Resolved: (1) That the Section welcomes papers from any of its members, whether personally known to the officers of the Section or not, and that all members should feel free to present papers at the meetings.

(2) That it is intended to continue the present practice of holding meetings in May and December, and that any member desiring to present a paper should not wait for an invitation but should send an abstract several weeks in advance of the time for the meeting either to the officer of the Section representing that portion of the territory where the member lives, or directly to the Secretary-Treasurer, it being understood that the presentation of a paper may be postponed if the number of papers offered should be large, or if the Executive Committee has limited the topics for discussion at a particular meeting.

Professor A. Cohen reported for the Committee of the Section coöperating with the National Committee on Mathematical Requirements.

The value and pleasure of the meeting were enhanced by the fact that all those in attendance had lunch together, as guests of the members of the Department of Mathematics of Johns Hopkins University. The appreciation of the Section for the hospitality of these gentlemen throughout the day was expressed by a cordial vote of thanks.

The following papers were presented:

(1) "On a remarkable property of $(a + b\sqrt{-n})^n$, where n is of the form $4m + 3$" by Mr. WM. E. HEAL;

(2) "An arithmetical pyramid" by Dr. J. R. MUSSELMAN;

(3) "Multiple-valued solutions of Laplace's equations" by Mr. C. A. SHOOK;

(4) "Recent progress in hydrodynamics" by Professor F. D. MURNAGHAN;

(5) "An extension of Ptolemy's theorem" by Professor FRANK MORLEY;

(6) "Variation of latitude" by Mr. W. D. LAMBERT;

(7) "The fluctuating attitude toward mathematics" by Mr. HARRY ENGLISH;

(8) "Minimal curves" by Dr. L. M. KELLS, U. S. Naval Academy (Introduced by Professor G. R. Clements).

Abstracts of seven of the papers follow below, the numbers corresponding to the numbers in the list of titles:

1. Writing $(a + b\sqrt{-n})^n = P + Q\sqrt{-n}$, Mr. Heal inquired whether P and Q are each separable into three rational factors. It has been known since the time of Euler that this is true for $n = 3$. In fact $P = a(a + 3b)(a - 3b)$, $Q = 3b(a + b)(a - b)$. Mr. Heal has established the theorem for all prime values of n less than 100, and believes that it is true in general.

2. A three-dimensional series of numbers was built up by Dr. Musselman, following a given law, which cut by transverse planes form an arithmetical pyramid. The numbers in these planes can be used to give a solution of the Problem of Points for three players who are equally skillful.

3. In his paper Mr. Shook showed how to construct the Green's func-

general interest of the meetings could be increased, and the labors of the Executive Committee lightened, if the various members would feel more free to offer discussions on topics of either a scientific or pedagogic nature which they have found interesting.—EDITOR.

tion, G, for a Riemann space of two sheets. This is done as follows: Let R denote the distance from the fixed point (r', φ', z') to any point (r, φ, z). Let R' denote the value of R, when φ is replaced by the complex variable α. Let $f(\alpha)$ denote any analytic function of α which (a) has a simple pole with unit residue at the point $\alpha = \varphi'$ and (b) is periodic with period 4π in both α and φ'. Then form the integral with respect to α having for integrand $1/R' \cdot f(\alpha)$, the path being so chosen that it includes the point $\alpha = \varphi'$, but no other singularity of the integrand. This integral multiplied by $2\pi i$ is the desired function G, with pole at (r', φ', z'). This function is single-valued in the Riemann space, but in ordinary space it is double-valued. Let G' denote the Green's function with pole at $(r', -\varphi', z')$, namely the image of the pole of G in the branch membrane. Then the difference $G - G'$ turns out to be the potential due to a semi-infinite plane under the influence of a unit charge of electricity at the point (r', φ', z'). In this difference the value in the first sheet of space is the one taken. The pole of G', being in the second sheet, does not cause an infinity to occur at that point in the first sheet. In that position it is, so to speak, harmless. Several possible extensions were indicated, such as curvilinear branch line and closed branch line.

4. Dr. Murnaghan spoke on the recent advances in the theory of resistance of fluids which have been made in two different directions: (*a*) by the Italian and French mathematicians, following the lead of T. Levi-Civita, and H. Villat, and (*b*) by the German workers in applied mathematics, following the lead of Prandtl and von Karman. The results obtained by the Germans have been up to the present the more useful to the practical men who work on the design of aëroplanes.

6. Mr. Lambert's paper dealt with the latitude observations of the International Latitude Service and particularly with the observations at Ukiah, Calif. These show on their face a progressive increase of latitude there of almost 0″.01 a year, an increase which has been interpreted by a well-known geologist as a northward creep of the surface crust at Ukiah over the underlying strata. Mr. Lambert showed that the other stations of the Latitude Service showed changes of latitude of the same order of magnitude, some having greater changes than Ukiah, and that all of these changes could be accounted for within a reasonable margin of error by assuming: (a) a purely fictitious change in latitude common to all stations and due to a cumulative error in the star places used; and (b) an actual change of latitude due to a displacement of the North Pole towards the American continent along the meridian of 77° West at the rate of about 0″.0050 a year. These deductions are limited to the years 1900–1917 inclusive. It was found that the latitude observations were accurate enough to give some information regarding the figure of the earth. They confirm in a general way Helmert's results from gravity observations that if the Earth is considered as an ellipsoid of three unequal axes, the shortest equatorial radius is 230 meters less than the longest one and lies in longitude 107° West. Attention was also called to Problem 2872, proposed by the author in the MONTHLY for January, 1921;[1] the

[1] Solved in this number of the MONTHLY, 227.

results there stated were found useful in discussing the latitude observations. The detailed investigation will appear in print as a special publication of the U. S. Coast and Geodetic Survey (no. 80); a shorter account appeared in the *Journal of the Washington Academy of Sciences*, January 19, 1922.

7. Mr. English said that the general trend of all opinion in the world seems to be a fluctuating one. The attitude towards mathematics is no exception, as to importance of methods of study and content of courses. The western part of the United States seems now to be dominating the eastern part, though it is not any too sure of itself. The reorganization which it is zealously pushing has many good features, though seemingly only one year of high school mathematics is required and that is somewhat polyglot in its nature. It may well apply to a junior high school course if that is a school of completion, but if it is to be the universal preparation for all senior high school mathematics, there is real danger along the line through the high schools and up into the colleges. There is naturally a haziness about the upper years, which may result fatally, especially in the hands of the majority of teachers, as definite details must be given if no harm is to result to pupils going from one teacher to another. It is a case of making haste slowly, giving careful consideration to all factors involved.

8. Dr. L. M. Kells first reviewed the well-known theory for minimal curves in the plane and in space, and then showed that the general equations of minimal curves in 4-space are

$$x_1 = \tfrac{1}{2}[(\lambda^2 - 1)F_1''(\lambda) - 2\lambda F_1'(\lambda) + 2F_1(\lambda) + i\{(\lambda^2 + 1)F_2''(\lambda) - 2\lambda F_2'(\lambda) + 2F_2(\lambda)\}],$$

$$x_2 = -\tfrac{1}{2}i[(\lambda^2 + 1)F_1''(\lambda) - 2\lambda F_1'(\lambda) + 2F_1(\lambda) + i\{(\lambda^2 - 1)F_2''(\lambda) - 2\lambda F_2'(\lambda) + 2F_2(\lambda)\}],$$

$$x_3 = \lambda F_1''(\lambda) - F_1'(\lambda),$$

$$x_4 = \lambda F_2''(\lambda) - F_2'(\lambda),$$

where $F_1(\lambda)$ and $F_2(\lambda)$ are arbitrary functions of λ and the primes indicate derivatives with respect to λ. Properties in 4-space analogous to those for ordinary space were considered.

G. R. CLEMENTS, *Secretary-Treasurer.*

THE APRIL MEETING OF THE OHIO SECTION.

The seventh regular meeting of the Ohio Section was held in the Physics Building, Ohio State University, Columbus, on April 14–15, 1922, in connection with the meetings of the Ohio College Association and allied societies. An afternoon and an evening meeting were held on Friday. On Saturday a joint meeting of two sessions with the Ohio members of the Society for the Promotion of Engineering Education was held. Chairman B. F. Yanney presided, being relieved by Professor K. D. Swartzel for an interval.

There were fifty-three persons in attendance, including the following thirty-three members of the Association:

R. B. Allen, W. E. Anderson, G. N. Armstrong, C. L. Arnold, C. B. Austin, Grace M. Bareis, R. D. Bohannan, E. H. Clarke, H. L. Coar, O. L. Dustheimer, T. M. Focke, Emma L. Konantz, H. W. Kuhn, W. C. McCoy, E. S. Manson, Jr., C. C. Morris, Amy F. Preston, S. E. Rasor, P. L. Rea, Hortense Rickard, Bernice Sanders, R. A. Sheets, Mary E. Sinclair, S. A. Singer, K. D. Swartzel, T. E. Trott, J. H. Weaver, C. E. White, R. B. Wildermuth, F. B. Wiley, C. O. Williamson, B. F. Yanney, and Antioch College represented by Dean P. C. Nash.

At the business session, the secretary reported a membership of seventy-eight and nine institutional members as against sixty-eight and eight, respectively, last year. Officers elected for this year are: Chairman, Professor H. L. COAR, Marietta College; Secretary-Treasurer, Professor G. N. ARMSTRONG, Ohio Wesleyan University; Third member of the executive committee, Professor J. H. WEAVER, Ohio State University. A committee of seven was elected with power to appoint and organize six or more sub-committees, to investigate the mathematics situation in Ohio with respect to the following six aspects at least: the state requirements and privileges, elementary school courses, high school courses, college entrance requirements, college courses, and teacher-training. This committee is to bring in a report, with recommendations, at the next annual meeting of the Section.

A majority of those in attendance joined with the Ohio College Association in the evening dinner at the Ohio Union, which was followed by an address by Dr. Thomas S. Moran, Purdue University.

The following papers were presented at the three sessions:

(1) Chairman's Address: "Some aspects of the mathematical situation in Ohio" by Professor B. F. YANNEY;

(2) Discussion: Professor E. H. CLARKE and Professor F. E. LANDSITTEL, Supervisor of High Schools, Ohio State University;

(3) "Chinese algebra, 'the precious mirror of the four elements'" by Professor EMMA L. KONANTZ;

(4) "The high school-college problem" by Miss MARIE GUGLE, Assistant Superintendent of Schools, Columbus (by invitation);

(5) "Simplification of the proofs of two statistical formulæ by the use of the calculus: (*a*) the moment formula, (*b*) the line of regression" by Professor C. C. MORRIS;

(6) "A theorem in geometrical optics" by Professor J. H. WEAVER;

(7) "The mathematical justification of a fundamental postulate of the theory of relativity" by Mr. DIO L. HOLL, Ohio State University (by invitation);

(8) Report on the Toronto meeting with special reference to "Research problems for college teachers" by Professor MARY E. SINCLAIR;

(9) "Structure and style of mathematical text books" by Professor H. L. COAR.

(Joint meeting with the Ohio members of the S. P. E. E.)

(10) "First lessons in calculus for engineering students" by Professor E. F. CODDINGTON, Ohio State University;

(11) "Mathematics and engineering in the Antioch program" by Dean P. C. NASH;

(12) "An experiment in freshman mathematics for engineers" by Professor K. D. SWARTZEL.

(Additional papers by members of the S. P. E. E.)

Abstracts of the papers follow below, the numbers corresponding to the numbers in the list of titles:

1. Chairman Yanney, in his opening address, considered some aspects of the mathematical situation in Ohio, the immediate occasion of the address being the recent ruling of the State Department of Education to the effect that the unit of mathematics, hitherto required as one of the constants in every high school curriculum, is no longer required. The whole situation was reviewed, and it was suggested that a committee of seven be appointed to investigate the situation and to bring in a report with recommendations at the next annual meeting of the Section.

2. (*a*) In his discussion, Professor Clarke called especial attention to a study reported by Marsh in *Educational Administration and Supervision* for November, 1921. Marsh's results seem to indicate conclusively that one year of algebra produces a marked beneficial effect upon a pupil's later work.

(*b*) Professor Landsittel presented the position of the state educational authorities with reference to mathematics in high schools. The elimination of the one-unit requirement in mathematics from the list of constant studies prescribed by the state for high schools is not to be understood as an act in contravention of entrance requirements of the colleges. The indispensability of due preparation in mathematics on the part of entrants to standard college courses is fully recognized. The subject as a requirement is to be waived in general only in the cases of students markedly deficient in mathematical ability but possessing sufficient capacity in other lines to make possible creditable graduation from the high school. In the judgment of the speaker these students are exceedingly limited in number.

3. Professor Konantz discussed the Chinese Algebra of Chu Shih Chieh published in 1303. A short resumé of the foundations upon which Chu had to build and an explanation of the old Chinese methods of computation were followed by a discussion of the four elements and the process of finding the roots of higher degree equations. This process was shown to be precisely the same as Horner's method of root extraction. Chu's arithmetical triangle was shown to be the same as Pascal's triangle. The greatest work of the Chinese mathematicians was in arithmetic and algebra and Chu's "Precious Mirror" shows the height to which they attained.

4. The high school-college problem in mathematics teaching was discussed by Miss Gugle. One difficulty is that there are usually great gaps in the continuity of the subject matter. Another is that instructors consider themselves teachers of algebra or of geometry instead of teachers of mathematics. Also by giving material not suitable to the pupil's needs, the teacher develops in him a

distaste for mathematics so that he loses faith in his own ability. There are too many failures, expensive both to the pupil and to the public. We as teachers must find a way or make way for others who will; for pupils must be trained to succeed, not to fail. Public schools demand that teachers be trained in the art and science of teaching. Colleges, too, must realize that the strongest and best teachers are needed to teach college freshmen. Much can be done when the representatives of high school and college confer and in that way bring about a better mutual understanding.

5. Professor Morris emphasized the importance of a knowledge of the calculus on the part of the student of statistics. He exhibited calculus proofs of certain statistical formulæ, the algebraic proofs of which are complicated and difficult to follow.

6. Professor Weaver, following a suggestion in Pappus's comments on Euclid's *Optics*, showed that if rays of light emanate from two sources in a plane P, such that the rays from the sources form at the eye a constant angle which revolves about an axis parallel to P, then the path of either of the sources is a hyperbola provided the rays are not refracted. If, however, the rays are refracted at a second plane Q, the path of a source in plane P is a curve C of degree 8. He also pointed out some properties of C.

7. Mr. Holl showed that the Newtonian transformation for the uniform rectilinear motion of a light emitting source gives unequal light velocities in opposite directions, a moving point source now generating an elongated spheroid light volume, but in postulating constant light velocity in all directions we have the Lorentz form, out of which arises the invariant D'Alembert form of differential equation for light propagation, and a sphere light volume for a moving source. This puts in mathematical language the second postulate of Special Relativity in which light velocities are invariant. The transformation shows the correction for Newtonian mechanics for uniform rectilinear motion as well as the interdependence of time and space.

8. Professor Sinclair reported the discussions given at the Toronto meeting of the Association by Professors Oswald Veblen and G. A. Bliss. The former centered his discussion about foundations of geometry. He urged that more should be done in developing the assumptions, much of it elementary in character but demanding reflection and imagination. He also questioned whether the study already made might not react more directly on the teaching of geometry. Professor Bliss emphasized the fact that research is the discovery of a problem on which to work. One needs enthusiasm, imagination, and somewhat of mathematical maturity. He spoke of the fertile field of the application of the calculus of variations to problems, many of them calling for methods peculiar to the problem, but often only a moderate amount of the theory. Recent research has applied itself to new problems and also to extensions of the solutions of problems by Newton and his contemporaries. The reviewer concurred with Professor Bliss in recommending the attractiveness of this field, and sketched some problems as typical. (See *1922*, 101–103).

9. Professor Coar spoke on mathematical text books, especially those on elementary subjects. He mentioned that too little emphasis is placed in our books on the use of mathematics as a language and upon its interpretation in terms of everyday life. Elementary texts should be more condensed and not be reference books. In any subject only a few well-defined principles are needed. These should be mastered before statement in the form of rules. Analytic geometry should emphasize analysis. Thus far most texts have failed along this line. In writing elementary texts, we should keep in mind the student rather than the subject-matter.

10. Professor Coddington explained his methods of illustrating the general rate meaning, not time-rate meaning, of a differentiation by means of a few simple numerical problems, before attempting to define differentiation. This is done because it is thought that the student may thus acquire a better appreciation of the meaning of a derivative than from the formal definition in terms of concepts such as function, limit, variable, etc., which he does not understand.

11. In the Antioch experiment the amount of actual engineering taught is reduced from that of the conventional technical school to allow, first, more time for a broad cultural education, and second, more time for general business courses needed by the engineer. The coöperative plan is used to allow the student to get actual experience in his vocation. Outlines of the courses of instruction in various branches of engineering were presented by Dean Nash. One year of mathematics is required of all students. Students are segregated into groups of about equal mathematical ability, and those not competent to handle elementary algebra are required to make up the deficiency, without credit, in the academy. The other students take two weeks for a study of two or three principles of advanced algebra, devoting the rest of the semester to trigonometry. The second semester is spent in a combined study of analytical geometry and business graphs and statistics. These are combined, first, to give something in the actual experience of the student which relates the abstract ideas of analytical geometry, and, second, to give him the power of analyzing business graphs and statistics from a theoretical point of view.

12. In describing an experiment in segregation of freshmen in mathematics in the College of Engineering of The Ohio State University, Professor Swartzel spoke of (*a*) the reasons for making the experiment; (*b*) the ten-lesson review in sub-freshman mathematics preceding the segregation; (*c*) the uniform test and other considerations upon which the segregating classification was based; (*d*) the semester records of the two thirds retained in the freshman mathematics and of the one third reviewing the more advanced portions of sub-freshman mathematics; (*e*) a comparison with the records of previous years showing a decrease in failures and withdrawals from 32 per cent. to 10 per cent. in the case of freshman mathematics and from 32 per cent. to 17 per cent. in the case of the freshman and sub-freshman mathematics combined. There were corresponding and material increases in the numbers passing with higher semester standing.

G. N. ARMSTRONG, *Secretary-Treasurer.*

THE APRIL MEETING OF THE ROCKY MOUNTAIN SECTION.

The sixth regular meeting of the Rocky Mountain Section was held at the State Teachers College, Greeley, Colorado, on April 14–15. Sessions were held on Friday afternoon and Saturday morning. The presiding officer was Professor G. W. Finley of the State Teachers College.

There were thirty in attendance, including the following eleven members of the Association:

I. M. DeLong, B. F. Dostal, A. R. Fehn, G. W. Finley, Philip Fitch, J. C. Fitterer, H. A. Howe, Claribel Kendall, G. H. Light, J. Q. McNatt, H. E. Russell.

Those in attendance were royally entertained at a six-thirty dinner in the Club House by Professor and Mrs. Finley. Professor LIGHT was elected chairman and Professor FEHN, vice-chairman, for the meeting to be held at the University of Colorado next year. A committee, consisting of Professor DeLong and Mr. Fitch, was appointed to draw up suitable resolutions upon the death of Dr. G. B. Halsted. It was also voted to extend an invitation to the national Association to hold its next meeting at the University of Colorado in September of this year or as soon thereafter as possible.

The following papers were presented:

(1) "Certain congruences determined by a given surface" by Dr. CLARIBEL KENDALL;

(2) "Kepler's problem for high planetary eccentricities" by Dean H. A. HOWE;

(3) "On the parametric equations of straight lines of which certain polar curves are envelopes" by Mr. PHILIP FITCH;

(4) "Games in mathematics teaching" by Mrs. LAURA C. GRAVES (by invitation);

(5) "A problem in mensuration" by Mr. J. Q. MCNATT;

(6) "The application of hyperbolic functions to transmission line problems in engineering" by Mr. B. F. DOSTAL;

(7) "The content of a course in plane geometry" by Mr. FITCH;

(8) "Population curves" by Professor J. C. FITTERER.

Abstracts of papers follow below, the numbers corresponding to the numbers in the list of titles.

1. Miss Kendall gave formulas which she had developed for obtaining the curves on a surface which would give the developables of any congruence associated with the surface. A line of the congruence was given for every point on the surface. She also gave the formula for obtaining the focal points on any such line. These results were applied to several special congruences and some interesting relations among the lines determining these congruences were obtained. Several of these lines are lines of the osculating quadric at the point and are in harmonic relation to one another.

2. Dean Howe gave a method for determining to a very close approximation the position of asteroids, except in the cases where the eccentricity is very great.

3. Mr. Fitch demonstrated a short method for finding the equations of lines traced by reflected rays of light, applying the same to known caustic curves.

4. Mrs. Graves suggested that all elementary mathematics should be taught after the fashion of the old spelling bee.

5. The problem considered by Mr. McNatt was to find the radius of the sphere which displaces the maximum amount of water contained in a conical vessel.

6. Mr. Dostal reviewed recent developments in the applications of the hyperbolic functions to loaded and balanced telephone lines and cables, and to power transmission lines.

7. This paper dealt with the subject matter, fundamental concepts and elementary principles of plane geometry. Mr. Fitch pointed out the relation of these concepts to those of higher mathematics and their use in other subjects.

8. Professor Fitterer showed that the hyper-tan curve, $y = a \tanh bx + c$, closely graphs population data. Its use in municipal and state problems involving probable future growth constituted an important application.

G. H. LIGHT, *Secretary-Treasurer.*

ORGANIZATION MEETING OF THE SOUTHEASTERN SECTION.

On April 29, 1922, mathematicians of the Southeastern States met in the Main Building of Georgia School of Technology, Atlanta, Georgia. There were sixty-three present at the meeting, of which number the following fifteen are members of the Association:

D. F. Barrow, J. B. Coleman, T. R. Eagles, Floyd Field, Tomlinson Fort, Miss Leslie Gaylord, J. F. Messick, A. B. Morton, M. T. Peed, W. W. Rankin, Jr., H. A. Robinson, Douglas Rumble, W. V. Skiles, D. M. Smith, R. P. Stephens.

At the business meeting it was decided to present a petition to the Trustees of the Association asking permission to form a Southeastern Section of the Association, to include the following states: Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee. After the program all present were entertained at lunch by Georgia School of Technology.

The officers elected are Professor FLOYD FIELD, Georgia School of Technology, Chairman; Professor R. P. STEPHENS, University of Georgia, Vice-Chairman; Professor W. W. RANKIN, JR., Agnes Scott College, Secretary-Treasurer. The Program Committee is composed of Professor W. W. Rankin, Jr., Chairman, Professor J. B. Coleman, University of South Carolina, and Professor Tomlinson Fort, University of Alabama.

The following program was carried out, abstracts being given with numbers to correspond to those of the program:

(1) "Some possibilities of the slide rule" by Professor D. M. SMITH;

(2) "Marking systems at the University of Georgia" by Professor D. F. BARROW;

(3) "Zero and infinity in elementary mathematics" by Professor J. F. MESSICK;

(4) "History of mathematics" (illustrated with slides) by Professor W. W. RANKIN, JR;

(5) "Einstein theory of relativity" by Professor W. S. NELMS, Emory University (by invitation).

1. In the first section of Professor Smith's paper it was shown that the theory of all fundamental operations of the slide rule flows directly from the definition of the logarithmic scale and from the fact that three units of length are used. The second section discussed the formulation of working rules for the solution of difficult problems when the student is unfamiliar with logarithms. The final section was devoted to certain advanced topics, including the solution of triangles, a type of engineering problem in maxima and minima, and solutions of the quadratic and cubic.

2. Dr. Barrow outlined the history of the marking systems used at the University of Georgia. He then exhibited some data, collected with the help of Mr. A. H. Stevens, which showed the variability of individual instructors in their distribution of high and low grades, and compared them with the distribution for the whole faculty.

3. Professor Messick's paper dealt primarily with the expressions $0/n$, $n/0$, ∞/n, n/∞, and the difficulties of teaching these to freshmen, with their meager knowledge of limits, and the subsequent troubles with the trigonometric functions. It attempted to show that the algebras could and should, by elementary methods, include a discussion of the infinite roots of the quadratic equation along with that of the zero roots. It was pointed out that otherwise some of the problems of analytics, particularly that of finding the asymptotes of the hyperbola, could not be intelligently comprehended by the student.

4. Professor Rankin pointed out that in some peculiar way the mathematicians have allowed an acquaintance with Cæsar, Homer, and Shakespear to count for culture and at the same time have permitted a knowledge of the work of Pythagoras, Euclid, Archimedes, and Newton to be regarded as sordid and commonplace. The failure of the mathematician to appreciate his forefathers has lost almost completely some of the outstanding men, such as Archimedes and Newton, both of whom are generally thought of as physicists, whereas they were also the greatest mathematicians of their day. The mathematician who forgets Thales, Pythagoras, Euclid, Archimedes, Diophantus, Apollonius, Cavalieri, Pascal, Fermat, Descartes, Napier, Newton, Leibnitz, the Bernoullis, Cauchy, and Gauss is no more worthy of the heritage that they have left him than the American who forgets Washington, Jefferson, Lee, Roosevelt, and Wilson.

5. Professor Nelms discussed Einstein's Relativity from the standpoint of a system of mathematics rather than from the idea of a theory of the physical universe. Several postulates were stated, which may be taken as the fundamentals or axioms of the system. An outline was given showing how these postulates would lead to the well-known deductions from the theory: world lines, variable space and time units, etc. Why the velocity of light is to be considered the maximum velocity of the physical universe was discussed from the physical and the Lorentzian transformation equation standpoints.

W. W. RANKIN, JR., *Secretary-Treasurer.*

SPANISH AND PORTUGUESE SYMBOLS FOR "THOUSANDS."

By FLORIAN CAJORI, University of California.

In old Spanish and Portuguese numeral notations there are some strange and curious symbols. In a contract written in Mexico City in 1649 the symbols "7U291*e*" and "VIIUCCXCI*ps*" each represent 7291 pesos. The U, which here resembles an O that is open at the top, stands for "thousands."[1] I. B. Richman has seen Spanish manuscripts ranging from 1587 to about 1700 and Mexican manuscripts from 1768 to 1855, all containing symbols for "thousands" resembling U or D, often crossed by one or two horizontal or vertical bars. The writer has observed that after 1600 this U is used both with Arabic and with Roman numerals; *before 1600 he has seen it used with Roman numerals only.* As the Roman notation does not involve the principle of local value, U played in it a somewhat larger rôle than merely to afford greater facility in the reading of numbers. Thus VIUCXV equals $6 \times 1000 + 115$. This use is shown in MSS. from Peru of 1549 and 1543,[2] in MSS. from Spain of 1480[3] and 1429.[4]

We have seen the corresponding *type symbol* for 1000 in a business blank of Mexico City, 1802, in eighteenth century books printed in Madrid,[5] and in modern reprints of seventeenth century documents.[6] In these publications the printed symbol resembles the Greek sampi ϡ for 900, but it has no known connection with it. In books printed in Madrid [7] in 1655 and 1646, the symbol is a closer imitation of the written U, and is curiously made up of the two small printed letters, "*l f*," each turned half way around. The two inverted letters touch each other below, thus "$\overline{lf}$." Printed symbols representing a distorted U have been found also in some Spanish arithmetics of the sixteenth century. The Spaniards call this symbol and also the sampi-like symbol a *calderón*.[8] A recent writer is in error when he states that these symbols were called *cuento*; *cuento* signifies, not one thousand, but one million.

The present writer has been able to follow the trail of this curious symbol U from Spain to northwestern Italy. In A. Cappelli's *Lexicon*[9] is found the follow-

[1] F. Cajori, "On the Spanish symbol U for 'thousands,'" *Bibliotheca Mathematica*, Bd. XII, 1912, p. 133.

[2] *Cartas de Indias publícalas por primera vez el Ministerio de Fomento*, Madrid, 1877, pp. 502, 543, facsimiles X and Y.

[3] José Gonzalo de las Casas, *Anales de la Paleografia Española*, Madrid, 1857, laminas, 87, 92, 109, 110, 113, 137.

[4] Liciniano Saez, *Demostracion Histórica del verdadero valor de todas las monedas que corrian en Castilla durante el Reynado del Señor Don Enrique III*, Madrid, 1796, p. 447.

[5] Liciniano Saez, *op. cit.*

[6] Manuel Danvila in *Boletin de la Real Academia de la Historia*, tomo XII, Madrid, 1888, p. 53.

[7] *Teatro Eclesiastico de la primitiva Iglesia de las Indias Occidentales* . . . el M. Gil Gonzalez Davila, su Coronista Mayor de las Indias, y de los Reynos de las dos Castillas. Tomo segvndo. En Madrid. 1655.

Memorial, y Noticias Sacras, y reales del Imperio de las Indias Occidentales . . . *Escriuiale por el año de 1646.* Juan Diez de la Calle, Oficial Segundo de la Misma Secretaria.

[8] In Joseph Aladern's *Diccionari popular de la Llengua Catalana*, Barcelona, 1905, we read under "Caldero," "Among ancient copyists a sign ($\overline{lf}$) denoted a thousand."

[9] Adriano Cappelli, *Lexicon Abbreviaturarum*, Leipzig, 1901, p. L.

ing: "In the liguric documents of the second half of the fifteenth century we found in frequent use, to indicate the multiplication by 1000, in place of M, an O crossed by a horizontal line." This closely resembles some forms of our Spanish symbol U. Cappelli gives two facsimile reproductions[1] in which the sign in question is small and is placed in the position of an exponent to the letters XL, to represent the number 40,000. This corresponds to the use of a small *c* which has been found written to the right of and above the letters XI, to signify 1100. It follows, therefore, that the modified U was in use during the fifteenth century in Italy, as well as in Spain, though it is not known which country had the priority.

What is the origin of this *calderón*? Our studies along this line make it almost certain that it is a modification of one of the Roman symbols for 1000. Besides M, the Romans used for 1000 the symbols ⊂|⊃, $\overline{\text{I}}$, ∞ and ✝. These symbols are found also in Spanish MSS. It is easy to see how in the hands of successive generations of amanuenses, some of these might assume the forms of the calderón. If the lower parts of the parentheses in the forms ⊂|⊃ or ⊂‖⊃ are united, we have a close imitation of the U, crossed by one or by two bars.

Allied to the distorted Spanish U is the Portuguese symbol for 1000, called the "Cifrão."[2] It looks somewhat like our modern dollar mark $. But its function in writing numbers was identical with that of the calderón. Moreover, we have seen forms of this Spanish "thousand" which need only to be turned through a right angle to appear like the Portuguese symbol for 1000. Changes of that sort are not unknown. For instance, the Arabic numeral 5 appears upside down in some Spanish books and manuscripts as late as the eighteenth and nineteenth centuries.

A GENERAL CONSTRUCTION FOR CIRCULAR CUBICS.

By R. M. MATHEWS, Wesleyan University.

1. It is well known that any cubic curve can be generated as the locus of the intersections of a pencil of conics on four points with a projective pencil of lines. In practical work it is difficult to draw the conics and to effect the correlation involved in this construction. As a circular cubic passes through the circular points at infinity, the conics for such a curve may be specialized to a pencil of circles on two finite points. It remains, then, to find a simple and general method for effecting the correlation with the pencil of lines.

Schroeter and Durège in simultaneous papers[1] have shown that if each line pass through the center of the corresponding circle, the locus contains its singular

[1] Adriano Cappelli, *op. cit.*, p. 436, first column, Nos. 5 and 6.

[2] See the word "Cifrão" in Antonio de Moraes Silva, *Dicc. de Lingua Portuguesa*, 1877; in Vieira, *Grande Dicc. Portuguez*, 1873; in *Dicc. Comtemp. da Lingua Portuguesa*, 1881.

[1] H. Schröter, "Ueber eine besondere Curve 3^{ter} Ordnung und eine einfache Erzeugungsart der allgemeinen Curve 3^{ter} Ordnung," *Mathematische Annalen*, vol. 5, 1872, pp. 50–82.

H. Durège, "Ueber die Curve 3^{ter} Ordnung, welche den geometrischen Ort der Brennpunkte einer Kegelschnittschaar bildet," *ibid.*, 83–94.

focus, which is the intersection of the tangents at the circular points. Moreover, the general construction has been considered for special base points[1]. This paper explains a general and simple compass and ruler construction for the case of an arbitrary pair of base points.

2. Let Q and R be two fixed points on a variable circle which is cut again in S and T by two arbitrary fixed lines s and t through Q and R, respectively. The variable line ST cuts an arbitrary fixed line g in U. The variable line PU, drawn from a fixed point P, cuts the circle in A and B. The locus of A and B for the pencil of circles through Q and R is a cubic curve. We find the following properties of the figure.

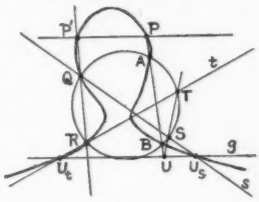

FIG. 1.

1. The lines ST are parallel, for $\angle TSQ = \angle QRT$ = constant.

2. There is a one-to-one correspondence between the circles and the pencil at P. For each circle cuts s and t in points S and T; the line ST determines U on g and so PU. Conversely, each line from P cuts g in a point U which determines one line in the fixed direction ST and so two points S and T concyclic with Q and R.

3. Q and R are on the locus. For PQ cuts g at U_Q and so the corresponding circle is determined; a similar consideration applies to R.

4. The circles of the pencil pass through the circular points at infinity, and thus the isotropic lines through P place them on the locus, which is, then, a circular cubic.

5. The circle through P puts this point on the curve.

6. When U is at infinity on g, then S and T are at infinity, and the circle on Q and R is replaced by the line QR and the line at infinity. Let the line through P parallel to g cut QR at P' and the line at infinity at F_∞, which is also on g.

7. The line g cuts the locus at F_∞ and at the points U_s and U_t where it meets s and t, respectively.

3. The given construction can now be shown applicable to any circular cubic. A circle through three points Q, R and A of the curve will cut it again in a finite point B. The line QR cuts the curve again in P' while AB does so in P. Then it is well known that PP' is parallel to the real asymptote. Let g, an arbitrary parallel to PP', cut the cubic in U_s and U_t. Thus lines s and t are determined as QU_s and RU_t, respectively. Our construction applied now on this basis will give a circular cubic which has in common with the given cubic the nine points, Q, R, P', A, B, P, F_∞, U_s and U_t besides the circular points at infinity. Accordingly, the cubics are identical.

4. The construction which Teixeira[2] derived analytically may be shown to be a special case of the foregoing. Take g through R and let it cut the cubic

[1] G. Loria, *Spezielle algebraische und transzendente ebene Kurven.* Leipzig, 1910, vol. 1, pp. 34–35.

[2] F. Gomes Teixeira, "Sur une manière de construire les cubiques circulaires," *Nouvelles Annales de Mathématiques*, fourth series, vol. 16, 1916, pp. 449–454.

again at U_s. Let the variable circle cut g again at H. Then as triangles QRU_s and SHU_s are similar:

$$\frac{U_sH}{U_sS} = \frac{U_sQ}{U_sR} = k, \text{ constant.}$$

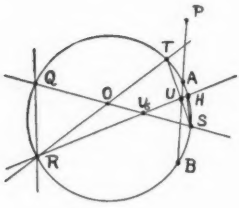

FIG. 2.

As the variable line ST moves parallel to itself, the segments it cuts on the fixed lines from U_s are proportional, so

$$\frac{U_sU}{U_sS} = k', \text{ constant.}$$

Thence

$$\frac{U_sH}{U_sU} = \frac{k}{k'} = c, \text{ constant.}$$

The procedure given is to draw PU arbitrarily from P to cut g at U; to determine H on g from the constant ratio just proved; and then to construct the circle through QRH to cut PU in points of the curve.

A GENERALIZATION OF THE STROPHOID.

By J. H. WEAVER, Ohio State University.

W. W. Johnson has given the following generalization for the strophoid.[1] Let A and B be two fixed points, and let two variable lines PA and PB make with AB angles ϕ and ψ, respectively. Let α be a constant angle and let P move so that

$$n\phi \pm m\psi = \alpha. \tag{1}$$

Then the locus of P is a strophoid. Equation (1) shows that there is associated with this set of curves a circle having a segment with AB as base in which the angle α may be inscribed.

In the following discussion some curves are developed which have associated with them the three conic sections.

Elliptic Case. Let there be an ellipse E with major axis AB, and from A and B let variable lines AP and BP be drawn making angles θ_1 and θ_2 respectively with AB. Let AQ and BQ be so drawn as to make angles $\pm m\theta_1$ and $\pm n\theta_2$ with AB. When the locus of Q is the ellipse E, the locus of P is a curve whose equation may be developed as follows. (In this development we will consider m and n as positive integers and relatively prime to each other.)

The slope of AQ is $\tan(m\theta_1)$ and of BQ is $\tan(n\theta_2)$. Then since Q is on E we have

$$\tan(m\theta_1)\cdot\tan(n\theta_2) = -b^2/a^2, \tag{2}$$

[1] "The Strophoids," *American Journal of Mathematics*, vol. 3, 1880, pp. 320–325. See also G. Loria, *Spezielle algebraische und transcendente ebene Kurven*, Berlin, vol. 1, 1910, p. 73. This lcass of curves includes the sextrix curves as a subclass. See Loria, l.c., p. 390.

where the equation of E is $x^2/a^2 + y^2/b^2 = 1$. Then using the same axes, the equations of AP and BP are

$$(AP) \qquad y = (x + a)\tan\theta_1, \tag{3}$$

$$(BP) \qquad y = (x - a)\tan\theta_2. \tag{4}$$

Eliminating θ_1 and θ_2 from (2), (3) and (4) we have

$$\begin{aligned} &a^2\left[\binom{m}{1}y(x+a)^{m-1} - \binom{m}{3}y^3(x+a)^{m-3}\cdots\right] \\ &\cdot\left[\binom{n}{1}y(x-a)^{n-1} - \binom{n}{3}y^3(x-a)^{n-3}\cdots\right] \\ &+ b^2\left[(x+a)^m - \binom{m}{2}y^2(x+a)^{m-2}\cdots\right]\left[(x-a)^n - \binom{n}{2}y^2(x-a)^{n-2}\cdots\right] \\ &= 0, \end{aligned} \tag{5}$$

an equation of degree $m + n$.

We will designate the curve (5) as $C_{m,n}$. The curve $C_{m,n}$ has $m - n$ asymptotes. These pass through the same point[1] if $a = b$. If $m - n$ is odd, there will be one asymptote parallel to the y axis. Its equation will be

$$x = \frac{nb^2 + ma^2}{nb^2 - ma^2}a, \qquad \text{or} \qquad x = \frac{na^2 + mb^2}{na^2 - mb^2}a,$$

the former when m is even and n odd, the latter when m is odd and n even.

THEOREM I. *The curve $C_{m,n}$ has an m-tuple point at A and an n-tuple point at B, and the tangents to the curve at each of these points make equal angles with each other.*

This theorem may be readily proved in the usual way.

THEOREM II. *The rth polar of B with respect to $C_{m,n}$ is $C_{m-r,n}$ $(r \leqq m)$, and of A is $C_{m,n-r}$ $(r \leqq n)$.*

By substituting $-b^2$ for b^2 we obtain the hyperbolic case.

Parabolic Case. Let there be given a parabola and let there be drawn through the vertex a line making an angle $n\phi$ with the axis and cutting the parabola in the point Q. Through Q draw a line parallel to the axis, and let this line be cut in the point P by a line through the vertex of the parabola and making an angle ϕ with the axis of the parabola. Then the locus of P is a parabolic strophoid. Its equation may be determined as follows: Let O be the origin, and let the vertex of the parabola be at the origin, and its axis the x-axis. Then the equations of the parabola and of the lines OQ and OP are

$$y^2 = 4ax, \tag{6}$$

$$(OQ) \qquad y = x\tan(n\phi), \tag{7}$$

$$(OP) \qquad y = x\tan\phi. \tag{8}$$

[1] See Loria, l.c., p. 392.

From (6) and (7) we may find the equation of the line through Q parallel to the x-axis, and eliminating $\tan\phi$ from this equation and (8) we get for the equation of the curve

$$y = \frac{4a\left[x^n - \binom{n}{2}x^{n-2}y^2 \cdots\right]}{\binom{n}{1}x^{n-1}y - \binom{n}{3}x^{n-3}y^3 \cdots}. \tag{9}$$

The curve (9) has an n-tuple point at the origin, and the tangents at this point make equal angles with each other.

Since (9) is of degree $n+1$ we will designate it as C_{n+1}.

THEOREM III. *The $(r+1)$th polar of the point at infinity on the axis of the parabola $y^2 = 4ax$ with respect to C_{n+1} is C_{n-r}.*

This may be proved by finding the polars in the ordinary way.

A Special Elliptic Case. In equation (5) let $m = 1$ and $n = 2$ and we obtain the cubic

$$b^2y^2(x+a) - 2a^2y^2(x-a) - b^2(x+a)(x-a)^2 = 0. \tag{10}$$

THEOREM IV. *If in the curve* (10) *a line is drawn through A cutting the curve in the points P and P', and the ellipse in C, then the tangents to* (10) *at P and P' and to E at C are concurrent.*

Proof: Draw through A another line cutting (10) in the points P_1 and P_1' and E in C_1. From the construction of the curve (10) it follows that (AC, PP') and (AC_1, P_1P_1') are harmonic ranges. Since these ranges have a point A in common they are perspective. Therefore PP_1, CC_1 and $P'P_1'$ are concurrent. If now we consider the lines AP and AP_1 to become coincident, the lines PP_1, etc., become tangents.[1]

The two following theorems may also be proved without difficulty:

THEOREM V. *The first polar of A with respect to* (10) *is the ellipse E.*

THEOREM VI. *The locus of the point of concurrence of the tangents in theorem IV is a cuspidal cubic, having B as cusp and the asymptote of* (10) *as asymptote.*

If in (10) $a = b$, the curve is the right strophoid, and if $b^2 = a^2/2$ it is the folium of Descartes.

A Special Parabolic Case. Let $n = 2$ in (9) and it becomes

$$2a(x^2 - y^2) = xy^2. \tag{11}$$

THEOREM VII. *Let a line be drawn parallel to the axis of the parabola $y^2 = 4ax$ cutting the parabola in the point C and the cubic* (11) *in the points A and B, and let tangents be drawn to* (11) *at the points A and B and to the parabola at C. These tangents are concurrent.*

The proof is similar to that of theorem IV.

THEOREM VIII. *The locus of the point of concurrence of the tangents in theorem*

[1] See Bassett, *An Elementary Treatise on Cubic and Quartic Curves*, Cambridge, 1901, p. 67.

VII is a cissoid which has its cusp at the vertex of the parabola and whose asymptote is the asymptote of (11).

THEOREM IX. *The parabola* $y^2 = 4ax$ *is the curvilinear diameter of the cubic* (11).

The proofs of theorems VIII and IX offer no difficulty and are therefore omitted.

HONOR TO PROFESSOR E. H. MOORE.

By H. E. SLAUGHT, University of Chicago.

At the two hundred twenty-second regular meeting of the American Mathematical Society, held at the University of Chicago April 14, 15, 1922, there was celebrated the twenty-fifth anniversary of the founding of the Chicago Section of this Society. The history of this Chicago Section is almost coincident with that of the University of Chicago where the great majority of its forty-nine meetings have been held. These meetings, which began in 1896 with the reading of fourteen scientific papers at the first informal session, gradually increased in attendance and importance until they were recognized by the Society as of coordinate standing with those of the parent organization in New York and were officially designated as regular Western meetings of the Society. The one just held was the seventeenth and largest of this kind, over one hundred members being in attendance.

The young and vigorous department of mathematics of the University of Chicago in 1896, with its remarkable trio of leaders, Professors E. H. Moore, Oskar Bolza, and Heinrich Maschke, naturally assumed the important rôle of leadership in fostering mathematical research in the Middle West, as reflected in the phenomenal growth of the Chicago Section. To those who know Professor Moore scientifically and personally, it is no surprise that he at once became, and still remains, the leader of leaders in this great work. It is universally recognized that he stands quite alone as regards the scope and strength of his influence on the development of mathematics in America, not only through his own researches but also through his impress upon the hundred and more men and women who have gone out with the Chicago doctorate in mathematics, upon the hundreds of Chicago masters and other graduate students, and upon all others who have directly or indirectly come within his dynamic presence and captivating friendship.

It was a foregone conclusion that any celebration of the last quarter of a century of mathematical activity in this country would center about Professor Moore, and hence a committee of his former students began more than a year ago to consider what kind of a testimonial would be most appropriate to present to him on this occasion. It was at once decided that none of the ordinary forms of gold or silver gifts, nor even a painted portrait, would adequately express the sentiments of his grateful admirers. They sought rather some token which

would for all time be a living and dynamic force for perpetuating his name in connection with his beloved science. Hence they decided to raise the sum of two thousand dollars among his former students and his associates in the Chicago Section, as the nucleus of an endowment fund to be used for assisting in the publication of mathematical treatises and researches in America,—a cause for which there is crying need of support. (Already those outside of this Chicago group are seeking to join in contributing to this fund and there are indications that it may grow into an endowment of large proportions as the years go by.)

However, the committee in their deliberations did not lose sight of the personal and friendly elements involved in these contributions, and hence they prepared a statement setting these forth in intimate terms as a prologue to the dedication of the fund. This Presentation Scroll was engrossed by Mr. C. L. Ricketts of Chicago in the style of the illuminated manuscripts of the Italian Renaissance, on the finest hand-made paper that can be produced, and bound in beautiful maroon leather surmounted by a solid gold monogram of the letters E H M. It was felt by the committee that nothing short of the very best in material and workmanship would suffice for this Presentation Scroll, and it is believed that no other illuminator in America could have excelled in the result produced. The Scroll contains the names of one hundred seventy-four contributors to the fund.

The following is the text of the Scroll:

To Professor Eliakim Hastings Moore,
Scholar, Teacher and Friend:

Conscious of the great influence which you have exercised upon the development of mathematical science throughout this country, particularly in the Middle West, during the last twenty-five years,

Admiring the outstanding qualities of your researches in various fields of mathematics,

Grateful for the inspiration and encouragement which you have given to those who have come to the University of Chicago to study mathematics,

Recognizing the large contribution which you have made to the creation and the growth of the Chicago Section of the American Mathematical Society, and

Deeply appreciative of the friendship which, during many years, you have bestowed upon those who have had the good fortune to know you;

The undersigned members of the American Mathematical Society, formerly students of mathematics at the University of Chicago, or members of long standing in the Chicago Section, have wished to use the opportunity afforded by the twenty-fifth anniversary meeting of the Chicago Section to present to you a testimonial, which is intended to link your name in the years to come with the development of mathematics in this country.

To this end they have contributed to a fund which is to be offered for trusteeship to the American Mathematical Society upon the following conditions:

The fund is to be known as the Eliakim Hastings Moore Fund;

The interest on the fund is to be used at the discretion of the Council of the

Society, and upon the recommendation of a committee appointed from time to time for this purpose, in furtherance of such mathematical interests as

(*a*) The publication of important mathematical books and memoirs,

(*b*) The award of prizes for important contributions to mathematics;

It being further recommended that during the next ten years preference be given to the former and that publication of Professor Moore's researches in General Analysis or in other fields shall have precedence over all other claims.

The fund is to be kept intact by the American Mathematical Society except in so far as it is used to aid in the publication of Professor Moore's researches. For this special purpose a part of the principal, not exceeding one third, may be used, provided the interest on the remainder be allowed to accumulate until the fund has been restored to its original value.

(Here follow the names of 174 contributors.)

CHICAGO, April 25, 1922.

AMONG MY AUTOGRAPHS.

By DAVID EUGENE SMITH, Columbia University.

24. SIR WILLIAM ROWAN HAMILTON AND THE EARLY DAYS OF QUATERNIONS.

It is well known that Sir William Rowan Hamilton (1805–1865) was one of the world's infant prodigies. Professor Alexander Macfarlane tells us of his considerable advancement in arithmetic at the age of three, of his ability to read Latin, Greek, and Hebrew at the age of five, and of his intimate familiarity with Italian, Sanskrit, and Arabic at the age of ten. At twelve he was contesting with Zerah Colburn, the American "calculating boy," and at sixteen he was reading Laplace's *Mécanique Céleste* and pointing out an error in the work of the great French master. He was thirty-eight, however, before he discovered the underlying principles of quaternions and it was not until 1853, ten years later, that he published his lectures on the subject. These lectures, in their initial form, were delivered at Trinity College, Dublin, in 1848.

The letter which follows was written in 1847 and has considerable interest in that it shows Hamilton's scientific activities at this time and refers to the monographs on quaternions which he had already published.

The letter, now in my collection, was written to Dr. James Booth and is as follows:

OBS^{Y} DUBLIN
March 5th, 1847

My dear Sir

Your note, dated the 12th of January, with its interesting accompaniments, did not reach me till a day or two ago,—which is the cause of its not having been sooner acknowledged. Allow me, as some return, to request your acceptance of my last contribution to the Proceedings of the Royal Irish Academy. There are, I think, some other papers of mine, of later date than any which you are likely to have seen—at least than any which I can have given you in 1845, as I printed several little things last year, availing myself so of the increased leisure gained by my retirement from the chair of the Academy. If, at *your* leisure, you will tell me the date of the last paper of mine on quaternions in your possession, I will try whether I cannot make your set

more complete:—since you have done me the honour of addressing the Society of which you are President, on the subject of my researches.

It could not, of course, be otherwise than honourable & gratifying to me, if the Literary and Philosophical Society of Liverpool should think fit, on your recommendation, to elect me a Corresponding Member. I do not know, however, that with the present claims upon my time, I have anything to promise in return.

Should you have mentioned the subject to any of the resident members, I hope that you will tell them that, through some accident, I did not hear of your intention till the day before yesterday.

I remain
my dear Sir
very truly yours
WILLIAM ROWAN HAMILTON

Rev. JAMES BOOTH, LL.D.

QUESTIONS AND DISCUSSIONS.

EDITED BY C. F. GUMMER, Queen's University, Kingston, Ont., Canada.

NEW QUESTION.

The following question should call forth some interesting answers, whether complete or not, from readers having a taste for constructive geometry.

46. A geometrical construction will often become impracticable in special cases where some of the construction points are imaginary, although the final result is real. Is there any system according to which a construction failing in this way may be replaced by one that will work?

For example, let a line l_1 cut a circle c_1 in P_1 and Q_1, and let a line l_2 cut a circle c_2 in P_2 and Q_2. If the four points P_1, Q_1, P_2, and Q_2 are real, the intersections of P_1P_2 with Q_1Q_2 and P_1Q_2 with P_2Q_1 may be found directly. If the four points are imaginary, the intersections named will still be real, and there ought to be a simple way of getting them as the points common to a line and a circle.

DISCUSSIONS.

In PROBLEM-NOTES (*1921*, 278) a problem in Skeleton Division, proposed by Professor F. Schuh, was quoted from *Nieuw Tijdschrift voor Wiskunde*, volume 8.

Professor Curtiss shows that this problem has the unique solution 7752341/667334. In Professor Bennett's "Remarks" it is shown that the same conclusion is reached without the assumption of irreducibility. Solutions of a number of puzzles of this kind by W. E. H. Berwick may be found in *The Mathematical Gazette*, January, 1922, pages 8 and 9. In all of these certain digits were given beforehand, and in several cases there is more than one solution. For other references see Note 2, in Problems and Solutions (*1921*, 37).

Mr. Ballantine develops some ideas on linear systems of functions with a view to generalizing the notion of derivative. Considering a Taylor expansion as a linear combination of the successive powers of the variable, he discusses some ways in which a linear combination of a more general sequence of functions may be regarded as a generalized Taylor expansion.

I. Solution of a Problem in Skeleton Division.

By D. R. Curtiss, Northwestern University.

In the June–July number of this Monthly (*1921*, 278) mention was made of a problem in skeleton division:

"The following calculation represents the development of an irreducible fraction to a repeating decimal:

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       -------
       ×××××××
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        -------
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                  ××××××
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                  ××××××
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Crosses indicate digits—all of which are possible. The repeating digits are shown by a line above the crosses. What irreducible fraction has been developed?"

The divisor is 667334, the dividend 7752341, the quotient $11.\overline{6168830001}\cdots$, the repeating digits being the nine under the dash.

First, as to the divisor:—The quotient, as an unending decimal, can be expressed as an infinite series

$$Q = \frac{m}{10} + \frac{n}{10^{10}} + \frac{n}{10^{19}} + \cdots,$$

where m and n are whole numbers. By the formula for the sum of a geometric series we have

$$Q = \frac{m}{10} + \frac{n}{10^{10}} \cdot \frac{1}{1 - 10^{-9}} = \frac{M}{10(10^9 - 1)},$$

where M is a whole number. Then, since dividend and divisor are relative primes by hypothesis, the divisor is a whole number which is a factor of $10(10^9 - 1)$. The prime factors of this number are 2, 3^4, 5, 37 and 333667. Since our divisor has six digits, it must be either 333667 or 667334. The former of these, however, is not the divisor, because the first three digits of line 7, and therefore of line 19,

would have to be 100 if the divisor were 333667, and the last indicated digit of the quotient would be 1 or 2. Multiply either into 333667 and subtract the result from a number of six digits whose last four are zeros, and the remainder cannot be a number beginning with 100. Thus 667334 is the only possible divisor.

We now show that the number in line 17 is 780000. The last indicated digit of the quotient must be 1, or there would be seven digits in line 18, and 1 is also the fourth digit of the quotient. This means that line 7 and line 19 begin with 10 or 11 or 12 or 13. The number in line 17, which is the sum of those in lines 18 and 19 (the former is the divisor itself), must then begin with 77 or 78 or 79 or 80. But the numbers in lines 15 and 16 are both even (the former terminating in a 0, and the divisor being even), hence their difference is even, and we have only 78 or 80 as possible first two digits in line 17. We dispose of 80 by noting that the numbers in lines 13 and 14 are even, so line 15 has an even number and a zero as its last two digits; to begin line 17 with 80 line 16 must end with a zero so that the eighth digit of the quotient would be 5, and line 16 ends with 70. Subtract from line 15, which ends with an even digit followed by a zero and the remainder cannot be 80.

We now know lines 17 and 18, and in consequence 19 and 7, the latter being 1126660. As line 5 ends with a zero, line 6 ends with a 4, and the third digit of the quotient is 6, since line 6 has seven digits. Line 5 is therefore 4116670, the sum of 112666 and 4004004. The first and second digits of the quotient are each 1, since lines 2 and 4 have but six digits apiece. These lines are, then, 667334, and a couple of additions brings us back to the dividend 7752341.

Note that the two decisive points are the number of factors in the repetend and the small remainder at line 17. If one wishes to amuse himself by constructing similar problems he would best pick this small remainder first, put it near the end of his operations, and build up the problem from it.

Remarks by A. A. Bennett, University of Texas.

This puzzle in skeleton division appears at first glance to be unadapted to any direct attack and to be probably capable of many solutions. A very brief examination is sufficient, however, to identify the division as that indicated by 7752341/667334. It may first be noticed that the continued decimal, which may be generated by $\times\times\times\times\times000\times/999{,}999{,}999$, and therefore by $\times\times\times\times\times\times/999{,}999{,}999$, is also generated by a fraction of the form $\times\times/\times\times\times\times\times\times$, as seen by the next to the last remainder. In this last fraction, if the common factors of numerator and denominator be removed, one has in the denominator a factor of 999,999,999, and this factor is at least a four-digit number. The factorization of 999,999,999 gives $3^4 \times 37 \times 333{,}667$, the last factor being a prime. A brief examination of 333,667 shows that this cannot itself be the divisor. It remains to test $2 \times 333{,}667$, any higher multiples being necessarily of seven figures. Now every six-figure multiple of 667,334 must be this number itself. Using this fact the steps may be rapidly retraced and the gaps filled.

The only alternative would be for the fraction $\times\times/\times\times\times\times\times\times$ to be of the

form $ab/(2997a) = \times\times\times\times\times/999{,}999{,}999$. Then $b \times 333{,}667 = \times\times\times\times\times\times$. Hence $b = 1$, or 2 and $\times\times\times\times\times\times = 333{,}667$ or $667{,}334$. Both suggested possibilities are readily tested and excluded, by virtue of the fact that the last remainder has six digits prior to carrying down the next zero. Thus for $b = 1$, we have a in the form $\times\times$ and $3a \times 2997$ or $8991a$ as the last quantity to subtract. In other words $(10000 - 8991)a$ is the remainder, or $1009a$, where a is a two-digit number. Even 99 is too small for a, so that $b = 1$ leads to a contradiction as before. The solution then is unique.

II. What is a Calculus?

By J. P. Ballantine, University of Michigan.

There is much room for speculation as to the possible ways in which the calculus can be generalized. With a hope of stimulating other answers, rather than any presumption of closing the question, I suggest the following answer.

Consider the functions (1), which we may call the elementary functions of the Newtonian calculus, or briefly the Newtonian elementary functions:

$$0, \quad 1, \quad \frac{x}{1!}, \quad \frac{x^2}{2!}, \quad \frac{x^3}{3!} \cdots. \tag{1}$$

Notice that the derivative of each of the set is its predecessor. In fact, the process of differentiation may be regarded superficially as the process of replacing any of the above functions as they appear in a linear combination by its predecessor.

Thus, if $F(x)$ is given by the equation:

$$F(x) = a + \frac{bx}{1!} + \frac{cx^2}{2!} + \frac{dx^3}{3!} + \cdots, \tag{2}$$

we may infer (under certain conditions of convergence) that the derivative $F'(x)$ is given by the equation

$$F'(x) = b + \frac{cx}{1!} + \frac{dx^2}{2!} + \cdots. \tag{2'}$$

The object of this interpretation of the process of forming a derivative is that it admits readily of a generalization. One can substitute in place of the functions (1) another set of elementary functions, and if as a set they satisfy certain conditions, one can build up a new calculus based on them. The process of differentiation is not altered, but the geometrical interpretation is. Take for instance the set of functions,

$$0, \quad 1, \quad \frac{x}{1}, \quad \frac{x(x-1)}{1\cdot 2}, \quad \frac{x(x-1)(x-2)}{1\cdot 2\cdot 3} \cdots. \tag{1'}$$

The calculus based on these is the well-known calculus of finite differences.

The derivative in this calculus does not mean the slope of the tangent at a point, but the slope of a secant through two points.

There is another way of looking at the derivative, which turns out to be more general. Consider an arbitrary function $F(x)$ developed by the Maclaurin series (2). The constants $a, b, c, \cdots$ are the values of the successive derivatives for $x = 0$. That is to say, b, c, etc., are the values of the first, second, etc., derivatives. With a little imagination, one could call a function itself its own derivative of order zero, from which it would follow that a is the value of the derivative of order zero.

Let us suppose we wished to base a calculus on the set of elementary functions:

$$f_1(x), f_2(x), f_3(x) \cdots.$$

Let us consider a very particular arbitrary function. Let it be particular in the fact that it is expressible as an infinite series, thus:

$$\phi(x) = a_1 f_1(x) + a_2 f_2(x) + a_3 f_3(x) + \cdots.$$

Then in our calculus, the values of the successive derivatives of $\phi(x)$ for $x = 0$ are by definition the constants $a_1, a_2, a_3, \cdots$. The values of the derivatives for other values of x may be defined by a horizontal translation of the function $\phi(x)$. In this way the derivatives may be defined as functions.

One of the properties to demand of a set of elementary functions is that they be linearly independent. Otherwise the derivatives are not uniquely defined.

They must also possess some property which will allow one to obtain the values of the constants without recourse to infinite determinants. Briefly, one must be able to eliminate simultaneously all except a finite number of the constants.

This latter property may manifest itself in a most unexpected manner. In the case of the Newtonian elementary functions it appears in the fact that all of the functions except the second vanish for $x = 0$. By use of this and the geometrical relation between the function and the derivative, one is able to obtain the successive constants.

In the case of the elementary functions of the calculus of finite differences, all after the nth vanish for $x = n - 2$, n any integer larger than one.

The foregoing examples were almost too trivial to mention. It remained for Fourier to find the eliminating property for the set of functions (3), and hence build up a calculus based on them.

$$\begin{array}{llll} \frac{1}{2}, & \cos x, & \cos 2x, & \cos 3x, \quad \cdots, \\ & \sin x, & \sin 2x, & \sin 3x, \quad \cdots. \end{array} \tag{3}$$

It is, that the integral of the product of any two different functions of the set between zero and 2π is zero.

The term analytic, as applied to a function, is now seen in a new light. With a slight change of meaning, in the Newtonian calculus an analytic function could be thought of as a function which is expressible in a certain interval by a Taylor

development with or without a remainder. Then we may say that a function is analytic in a particular calculus, if it can be handled in that calculus, i.e., if it can be expanded in terms of the elementary functions.

It is a familiar fact that there are functions expressible in a certain interval by a Fourier expansion, which cannot be developed in a Taylor expansion. In general whether a function is analytic or not depends entirely on the calculus under consideration.

We accept as commonplace the fact that the derivative of the nth derivative is a derivative of order $n + 1$, in much the same manner in which students in the grades accept the commutative and other laws of arithmetic. Now that we are dealing with a generalization of the calculus, our logic demands an investigation of the observance of the "laws of calculus." The particular law referred to could well go under the name of the "cumulative law." Any calculus which is obtained from the first generalization mentioned in this paper will obey the cumulative law. The calculus of Fourier does not.

Between the Newtonian and the finite difference calculus on the one hand and the calculus of Fourier on the other we have the calculus of difference quotients.[1] The elementary functions are:

$$1, \quad \frac{(x - x_1)}{1}, \quad \frac{(x - x_1)(x - x_2)}{1 \cdot 2}, \quad \frac{(x - x_1)(x - x_2)(x - x_3)}{1 \cdot 2 \cdot 3}, \quad \cdots. \tag{4}$$

The quantities $x_1, x_2, x_3, \cdots$ are any preassigned constants. The expansion of any analytic function in this calculus will be an infinite series of arbitrary constants multiplied into the successive functions (4). These arbitrary constants are called difference quotients, owing to their law of formation. In reality, however, they are the derivatives of this calculus. They have a geometrical significance, slightly different from that of the Newtonian calculus. In this calculus the cumulative law does not hold.

In summing, I would say that any equation defining the dependence of a function on one or more independent variables, written in a form containing arbitrary constants, may be regarded as a Taylor development of the function in a calculus. The form of the equation will define the calculus. An infinite calculus may be distinguished from a finite calculus by the number of constants. The calculus will consist of the study of the relation between the function and each of the derivatives, and will deal only with functions expressible by the corresponding Taylor development.

REMARKS BY THE EDITOR.

There are of course a number of ways of developing a calculus of linear functional operations, though it is probably unusual to transfer to a new operation the terminology of differentiation. In fact, it is often a matter of special importance to express a new operator in terms of the known operator $D = d/dx$ rather than to displace the latter as the fundamental element of the calculus.

[1] "Difference Quotients," this MONTHLY, *1919*, 53–59.

Though the idea is an old one, a good deal of its practical development is due to a group of mid-nineteenth century writers.[1] The more recent scientific statement of the theory from the analytic function standpoint is largely the work of Pincherle and Bourlet.[2]

With these last writers a linear operation may be said briefly to consist in a linear transformation on the coefficients in the Taylor development of an analytic function. Thus $D(a_0 + a_1x + a_2x^2 + \cdots) = b_0 + b_1x + \cdots$, where the b's are obtained by the transformation $b_0 = a_1$, $b_1 = 2a_2$, $\cdots$. For any operator A of this kind the linear property $A\{a_1f_1(x) + a_2f_2(x) + \cdots\} = a_1Af_1(x) + a_2Af_2(x) + \cdots$ will be true, always when the number of f's is finite, and in other cases under certain convergence conditions. Mr. Ballantine's first method gives a particular case of this, namely that in which $Af_{i+1}(x) = f_i(x)$ for the chosen fundamental system of functions.

To discuss the second scheme it is necessary to examine the way in which the derivatives of $\varphi(x)$ are defined for a value of x differing from zero. The definition by "parallel translation" implies that there exist relations $f_i(x+y) = \Sigma_j g_{ij}(x)f_j(y)$, and that the jth derivative of $f_i(x)$ is $g_{i,\,j+1}(x)$. It is clear that such relations do not exist for every set of elementary functions. For instance, if these consist of the even powers of x, no such development can be found for $(x + y)^2$, etc. It is a question therefore whether it is strictly correct to speak of the second scheme as more general than the first.

The first and second methods coincide if the elementary functions satisfy the addition equations $f_i(x + y) = \sum_{k=1}^{k=i} f_{i+1-k}(x)f_k(y)$. This is the binomial formula in the case of the Newtonian system, and is also true for the (equally Newtonian) factorial functions (1′).

The operation given by the second process will be one of Pincherle's linear operations only when the "cumulative" law holds. It is doubtful whether anything is gained by extending the name of successive derivatives to functions *not* obtained by the successive application of any one rule.

It is of course possible that an operation defined under the second scheme in the "cumulative" case might have been defined under the first by using a different system of elementary functions. A large class of linear operators A have the following properties: (i) $A(1) = 0$; (ii) the inverse A^{-1} exists.[3] By (i), A^{-1} involves an undetermined constant of "integration" which may be chosen so as to make $A^{-1}(1)$, $A^{-2}(1)$, $\cdots$ vanish when $x = 0$. Selecting arbitrary constants a_i within a certain field of validity, we may then construct a function $\varphi(x) = \sum_{i=1}^{i=\infty} a_iA^{1-i}(1)$ having at the same time the three properties $A^{i-1}\varphi(0) = a_i$, $B_1{}^{i-1}\varphi(0) = a_i$, and $B_2{}^{i-1}\varphi(0) = a_i$, where B_1 and B_2 are Mr. Ballantine's two operators for the system of functions 1, $A^{-1}(1)$, $A^{-2}(1)$, $\cdots$.

[1] See, among other works, Carmichael, *Treatise on the Calculus of Operations*, London, 1855.

[2] See especially Pincherle e Amaldi, *Le operazioni distributive*, Bologna, 1901, both for a thorough discussion of the whole matter, and for numerous references. A simple account of the theory may be found in Chapter VIII of Hadamard, *La série de Taylor et son prolongement analytique*, Scientia Series, Paris, 1901.

[3] It is supposed that A is defined on a power series, as above. $A^n(1)$ means $A^n(1 + 0x + 0x^2 + \cdots)$, and is also a power series.

Perhaps the most interesting questions raised by the discussion are those concerning the relations between the different schemes, and the extent to which these overlap or supplement one another. In particular, are all cumulative operations obtained under the second plan also obtainable under the first?

RECENT PUBLICATIONS.

REVIEWS.

Plane Trigonometry with Practical Applications. By L. E. DICKSON. Chicago, Benj. H. Sanborn and Co., 1922. 4to. 11 + 176 + 35 pages. Price $1.52.

Extracts from the Preface: "This book introduces at an early stage concrete applications of trigonometry to the elementary parts of navigation and surveying, which are the two simplest exact sciences, as well as to the two elementary topics of physics which are known as composition of forces and refraction of light. There is, too, a full explanation of the theory and construction of a Mercator map, a subject of great importance also in geography. Three separate chapters are devoted to these subjects. The necessary terms and ideas are explained at length and illustrated concretely. We thereby obtain an abundance of simple problems whose importance is so convincing that they cannot fail to arouse real interest. Actual experience with classes has firmly convinced the author that these practical applications offer the best means to drive home the principles of trigonometry and to make the subject truly vital. . . .

"The development of the subject is leisurely and the student is given ample time in which to digest each idea. There are given full and lucid explanations of all new terms and ideas. Lack of the precise knowledge of the mathematical meaning of terms is one of the chief sources of difficulty in the study of mathematics. Various terms which should be already familiar to students are re-defined. On the basis of careful readings both of the manuscript and proof sheets by various experienced teachers in high schools and colleges, it is believed that the presentation is throughout both simple and clear.

"The tables are as simple as possible, and accurate for computation to four significant figures, which are ample for all ordinary practical purposes. It is true that some delicate astronomical measurements justify computations with 5, 6, or 7 place tables; but no new theory is involved. The traverse table, which is necessary for navigation and surveying, is really a systematic list of the sides and angles of all right triangles of moderate size. Its additional headings aid in making the present exposition of navigation much simpler than was possible heretofore. The traverse table is extremely useful in all parts of trigonometry and its applications, partly by relieving the monotony of logarithmic computation, but chiefly for the instantaneous checking of computations.

"The chapters on navigation and surveying are each divided into two parts, this making possible either a brief, wholly untechnical, introduction to those applications, or a fuller treatment."

Contents—Chapter I: Trigonometric functions of acute angles, 1–18; Chapter II: Solution of right triangles by means of tables of the natural functions, 19–25; Chapter III: Traverse table; solution of right triangles by inspection; problems on forces and refraction of light, 26–33; Chapter IV: Logarithms, slide rules, 34–47; Chapter V: Solution of right triangles by logarithms, 48–58; Chapter VI: Navigation: dead reckoning. Part I, the sailings (true course assumed). Part II, finding the true course; compass corrections, 59–81; Chapter VII: Land surveying. Part I, balancing a survey, area (true bearings assumed). Part II, surveying instruments; finding true bearings, 82–102; Chapter VIII: Trigonometric functions of any angle, 103–114; Chapter IX: Solution of oblique triangles, 115–132; Chapter X: Relations between functions of several angles, 133–149; Chapter XI: Graphs of the trigonometric functions and their inverses, radians, 150–167; List and index of formulas, 169–170; Index, including index to definitions, 171–172; Answers to certain of the first five exercises of each set, 173–176; Tables, 1–35.

The numerous textbooks that have been prepared by Professor Dickson, to say nothing of his more technical work, have throughout been characterized by a

logical directness and independence of treatment that are as refreshing as they are rare. First year college students, while seldom consciously critical, reflect by their loss of interest and decreased comprehension every carelessness on the part of the textbook writer and of the teacher. The merits of such a treatment as that here given are so obvious that any remark that might seem to convey a reflection upon the minor details of style may be out of place. For the prospective user of this text the following points may be mentioned. The treatment differs markedly from that customary for engineering texts. Perhaps the difference may be balanced by the method of presentation, but as a text, two features are fairly obvious. Most of the numerous relations that the good student prefers to work out as occasion may demand, but which the poor student, unfortunately, prefers to memorize, are not tabulated conspicuously in this text. This has the disadvantages of failing to impress the important features at a casual glance despite the warnings in the text, and also of making future reference inconvenient. That this remark is not an unfair one will doubtless be granted by any one who glances at the text. For example, the definitions of the cotangent, secant and cosecant are not given directly in terms of the adjacent side, opposite side and hypotenuse, but these functions are defined as the reciprocals of the tangent, cosine, and sine respectively. The values of the functions of 30°, 45°, and 60° are left to exercises as are also the signs of the functions in the several quadrants. Even the formulas which are labeled are not displayed in heavier type to catch the eye. The second conspicuous feature of this text is the number of technical suggestions made but left undeveloped. These undoubtedly add interest but lengthen the amount of time spent. For example, there is a description of the slide rule but no exercises in its use. It is to be presumed that the author does not expect the class to make actual use of this most convenient instrument. From the description given, it is at least dubious if a student could pick up a facility in the handling of a slide rule, and in fact it is hinted that the booklet which usually accompanies the sale of the instrument is to be relied upon. One may question the real utility of descriptions of instruments which the student does not see and handle, while if the instruments are at hand for examination the brief description in the text is superfluous. Similar remarks apply to the surveying instruments. It would have been of interest to have included also the sextant on account of its interesting geometrical theory, if so much less interesting an instrument as the surveyor's transit is regarded as deserving three pages of discussion and a full page cut.

The author says in his preface, "The great majority of students of trigonometry, whether in the high school or the college, take it as their final course in mathematics. Hence the course should justify itself at the time and not be merely a stepping stone to further mathematical subjects. Without overlooking the needs of the few who will go further in mathematics, we may justify trigonometry to the others by demonstrating its great utility by means of simple applications to various subjects that are vital in the world today." For the student of considerable imagination if not for all students this purpose has been well achieved

here. One might be inclined to question the value of this point of view for certain classes of students. Might not one regard the few "practical" problems always found in current texts as a sufficient hint of the practical side of the subject? Might not a good student obtain an even clearer insight into the utility of the subject, granted the time to cover such a book as this, if spherical trigonometry and its applications were included at the expense of problems in plane navigation and the refraction of light? Such queries must be answered by the individual teacher, as well as the more fundamental question as to whether the subject of trigonometry merits the time that a book of this sort will require to cover satisfactorily. In any case this text is urged upon the consideration of prospective teachers of the subject for its original and beautifully logical treatment in simple, clear style of a hackneyed but important course in elementary mathematics.

ALBERT A. BENNETT.

Loose-Leaf Outlines in Mathematics. By ROBERT R. GOFF. Boston, The Palmer Company. *Algebra*, 1920, 31 pages. Price $ .50. *Observational Geometry and Numerical Trigonometry*, 1922, 35 pages. Price $ .50.

The ideal method of conducting a mathematical class may depend upon the personality of the teacher even more than upon the content of the course or the preparation of the pupil. While lecture courses in which the students take notes as a basis for subsequent private study may prove entirely satisfactory for graduate courses in a university, there may be a question as to whether this is usually an ideal procedure in a subject like mathematics. Lectures are well adapted to advanced students if the subject matter is readily absorbed and merely an intelligent memory is required. The standard technique in undergraduate instruction in mathematics is undoubtedly to assign portions of a text for home study, designate certain problems to be completed outside of class, discuss and explain difficult points, and spend the remainder of the class period in testing the mastery that the students may have acquired of topics already assigned.

Other modes of attack are possible. In some places home work is reduced to a minimum. Laboratory methods are occasionally very successful in the hands of an enthusiastic teacher. A feature may be made of open discussion, or the subject may be taken up in a "reading course." The work may be handled in the character of a puzzle. A significant question to be asked is, how far does the student in fact utilize the explanations in the text. It is the reviewer's experience that the mind of the college freshman, at least, reacts far more vividly to a single illustrative example than to any discussion, long or short, of the principles involved. The college student is at first, if not eventually, inductive and general statements while readily memorized are applied only with difficulty until numerous examples have emphasized their significance. A question which the teacher must keep constantly in mind is as to just how far the student should be allowed to acquire mere dexterity accompanied by memorized rules (something that the otherwise poor student enjoys), and how far the

processes of deduction in their more abstract aspects should be forced upon the youthful and not too receptive mind.

One can judge somewhat the popular taste by noting the wide sale of texts which are often little better than collections of well graded exercises and carefully detailed illustrative examples. Many books which are frankly exercises and nothing else fail in a wider appeal merely because they are not accompanied by sufficient material to be memorized. They are unpopular not because they have strained the material too thin, but because they give too little restful variety to the laboring student.

In high school work, independent thought on the part of the pupil must be even less stressed than in the first year at college. Rules and exercises must constitute the bulk of a course in mathematics. Must that be all? The loose-leaf system under present discussion appears to expect an answer in the affirmative. I will quote from the compiler's "Explanatory Note."

"Some of the aims of these Outlines are to help the student:

1. Organize the material.
2. Separate essentials from non-essentials.
3. Emphasize fundamentals and methods.
4. Summarize related facts and processes.

These Outlines can be used with any text book. Make the Outlines the basis of the recitation and use the text book for a reference and supply book.

A topic is begun by a discussion of its nature and methods. Let the pupils do the work guided by the teacher. In the simpler operations, several particular examples from arithmetic should be carried through; then the generalized conclusion made in algebraic form and put on the pages of the Outlines or on an inserted page. "Chalk and talk" is good here. Then there should follow the application to exercises.

Models should be made of every definition and process.

Noticeable results of the use of these Outlines are:

1. They increase interest as work done with them is the pupil's own creation.
2. They make a reference book which the pupil knows how to use.
3. Their use develops habits of systematic effort.
4. They give a clear view of each topic as a whole."

Except for the idea of a loose-leaf method the material is handled in a standard conservative fashion and with a minimum of words. There is little beyond a set of definitional abstractions and a tabulation of type formulas and cases, with numerous blanks to be filled out by the pupil. There are few details which can be regarded as exercises in the narrow sense. Rather we have here an outline of the sort that when completed the professional tutor would call a syllabus. This makes the use of a separate source of problems essential but entirely replaces for the average pupil any text book discussion.

The sort of movement which this and numerous similar outlines evidence is of importance in the educational life of this country,—vastly more important than any single outline could be.

ALBERT A. BENNETT.

Plane Geometry: Experiment, Classification, Discovery, Application. By C. ADDISON WILLIS. Philadelphia, Pa., Blakiston's Son & Co., 1922. 16 mo. 301 pages. Price $1.32.

Preface: "This text represents the experience and developing ideals of a quarter of a century

of geometry teaching. The philosophy and the methods set forth in it are those of the author's own class-room. He believes that a pupil learns more of the subject when it is presented as in these pages, and he is certain that every pupil who is taught by this method under the guidance of a teacher who is himself interested in his subject becomes inspired to learn and is willing to work to learn. An awakening of a love of the subject is a service that may be rendered to our pupils of every intellectual grade. The text is so arranged that it may be variously used. . . . A short course . . . A laboratory course . . . A complete course . . . Exercises . . . For exceptional pupils . . . Dedication: The conception of this work runs far back in the years. It is the author's contribution in the service of his profession. It is dedicated to all those many students of the grand old science, . . . , and to all those teachers who have keenly felt the need of a more sympathetic interpretation of its immortal truths.

"In the hope that it will influence better teaching and learning, and will help to upbuild and uphold a generation which will reverence our beloved geometry for its own sake, as well as for its uses inseparable from a great constructive civilization—the author sends this little volume forth upon its mission."

Introduction to Ballistics.[1] [By ALBERT A. BENNETT.] Washington, Ordnance Department, U. S. Army, 1921. 8vo. 259 + 23 pages. Price $1.35.

Contents—Preface, 1–2; § 1: General remarks, 3–5; § 2: Some elementary concepts in mechanics, 6–25; § 3: Some elements of interior ballistics, 26–41; § 4: An introductory discussion of exterior ballistics, 41–46; § 5: The equations of the trajectory in vacuo, 46–53; § 6: Action of air resistance, 53–68; § 7: Measurements of air resistance, 69–72; § 8: Tabulation of air resistance, 73–77; § 9: The ballistic coefficient, 78–82; § 10: The trajectory in air, 83–85; § 11: Elements of the trajectory, 85–98; § 12: Siacci's method, 99–110; § 13: The use of Ingalls' Tables II, 111–117; § 14: Ballistic tables based on numerical integration, 118–131; § 15: The computation of trajectories by numerical integration, 131–139; § 16: Deviation of the trajectory from the plane of fire, 140–147; § 17: Errors and the application of the theory of probability, 148–168; § 18: Range table conditions, 169–183; § 19: Variations from range table conditions, 184–188; § 20: Differences in altitude of gun and target, 189–198; 21: Wind effects, 198–210; § 22: Meteorological changes, 211–217; § 23: Rotation of the earth, 218–227; § 24: The meteorological message, 228–238; § 25: Proving Ground data, 239–244; § 26: Range tables, 245–258; Table of contents, 259. Supplement: Comparative sketch of the normal ballistic coefficient, 1–23.

A Course in Exterior Ballistics. Ordnance Textbook. [By R. S. HOAR.] Washington, Government Printing Office, 1921. 8vo. 127 pages. Price $1.00.

Extracts from the Introduction—"The work of the ballistic computer is divided into three parts: (1) the computation of the elements of standard trajectories; (2) the computation of differential corrections, whereby the elements of a standard trajectory may be corrected for nonstandard conditions; and (3) the utilization of the foregoing to construct range tables from firing records. . . . The first course of instruction in these new ballistic methods ever given in this country was given at the Ordnance School of Application in the winter of 1919–20 by Capt. Roger Sherman Hoar, Coast Artillery, then in charge of the Ballistic Section of the Proof Department at Aberdeen. This present book is based upon the papers used in that course, and uses the standard symbology and nomenclature established as above. It is assumed that the student is thoroughly grounded in algebra and plane trigonometry, and knows enough calculus to appreciate the meaning of a derivative, a differential, and a definite integral. On that basis, this book gives, in Chapters I to IV, the irreducible minimum of higher mathematics necessary to understand all points involved in the later chapters."

Contents—Introduction, 7–9; Chapter I: Partial differentiation, 10–13; II: Successive approximations, 14–17; III: Effect of differential variations, 18–27; IV: Finite differences, 28–33; V: Elements of the trajectory, 34–37; VI: History of exterior ballistics, 38–42; VII: The motion of a projectile, 43–46; VIII: Computation of trajectories, 47–52; IX: Derivation of auxiliary variables, 53–58; X: Range correction formulas, 59–69; XI: Angle of departure correc-

[1] For notice of *Physical Bases of Ballistic Table Computation* by Professor Bennett see this MONTHLY, *1920*, 372.

tion formulas, 70–72; XII: Deflection formulas, 73–75; XIII: Rotation of the earth, 76–82; XIV: Computation of differential corrections, 83–90; XV: Weighting factors, 91–95; XVI: Construction of a range table, 96–102; Supplement A: Trajectory computation by the tangent reciprocal method, 103–104; B: Explanation of the signs in the computation of differential corrections, 105–106; C: Dimensions of ballistic symbols, 107–108; D: Antiaircraft fire, 109–110; E: Derivation of two equations of Chapter VII, 111–113; F: A derivation of Theorem I, 114–115; G: New methods of trajectory computation, 116–119; H: Note on advancing difference formulas, 120–121; Index, 123–127.

NOTES.

The third volume of *Fundamenta Mathematicae* (see *1921*, 318) appeared in April. It contains 323 pages, consisting of 29 papers + problems proposed and lists of exchanges. The only American authors are R. L. MOORE, "Concerning connectedness im kleinen and a related property," 232–237, and J. R. KLINE, "A theorem concerning connected point sets," 238–239.

Volumes 85 and 86 of *Mathematische Annalen* (see *1921*, 135) have been published. The following articles are by American writers—In volume 85: A. J. KEMPNER, "Über die Separation komplexer Wurzeln algebraischer Gleichungen," 49–59; E. R. HEDRICK and W. D. A. WESTFALL, "The existence domain of implicit functions," 74–77; E. J. WILCZYNSKI, "Charakteristische Eigenschaften der isothermkonjugierten Kurvennetze," 208–212; E. KASNER, "The solar gravitational field completely determined by its light rays," 227–236. In volume 86: O. D. KELLOGG, "On the existence and closure of sets of characteristic functions," 14–17; E. H. MOORE, "On power series in general analysis," 30–39.

A. Hermann, 6 rue de la Sorbonne, Paris, is offering for sale the volumes in the mathematical libraries of Monsieur Lebon and Professor Camille Jordan, and Professor Pierre Boutroux.

The mathematical library of the late Paul Mansion (d. 1919), long professor of mathematics at the University of Ghent, is to be presented to the University of Louvain as soon as a library building has been erected. One of Professor Mansion's sons is a professor at the University of Louvain, and another is professor at the University of Liége.

In accordance with the terms of the Treaty, volumes from the various libraries of Germany are now being assembled at Leipzig for the University of Louvain. The ruins of the old L-shaped library still stand much as after the fire. The corner stone of the building for the great new library was laid July 28, 1921, and work on the foundations is now being carried on. The inscription on the corner stone is: "Lapis primarius Bibliothecae Lovaniensis nobiliter reficiendæ."

ARTICLES IN CURRENT PERIODICALS.

AMERICAN JOURNAL OF MATHEMATICS, volume 43, October, 1921: "On some properties of general manifolds relating to Einstein's theory of gravitation" by J. A. Schouten and D. J. Struik, 213–216; "Geometrical theorems on Einstein's cosmological equations" by E. Kasner, 217–221; "On the Fermat and Hessian points for the non-euclidean triangle and their analogues for the tetrahedron" by C. M. Sparrow, 222–225; "The Cauchy-Lipschitz method for infinite systems of differential equations" by W. L. Hart, 226–231; "Boundary value and expansion problems; formulation of various transcendental problems" by R. D. Carmichael, 232–270; "Reciprocity in a problem of relative maxima and minima" by J. K. Whittemore, 271–290.

Bulletin des Sciences Mathématiques, volume 46, February, 1922: "A propos de quelques livres sur la théorie de la relativité" by J. Villey, 61–96—March: "Vue d'ensemble sur les machines à calculer" by M. D'Ocagne, 102–144—April: "Sur les fonctions qui admettent un théorème d'addition algébrique" by H. Mineur, 156–176.

Il Bollettino di Matematica, new series, volume 1, nos. 1–3, 1922: "Su alcuni problemi relativi all'equivalenza dei poligoni" by C. Ciamberlini, 1–4; "Sui criteri di eguaglianza dei triangoli" by R. La Marca, 5–9; "Le soluzioni intere della equazione $1/x + 1/y = 1/z$" by C. Ruggeri, 10–15; "Aggiunte ad una nota su 'Particolari progressioni aritmetiche e geometriche'" by L. Tenca, 16–21. "Sezione storico-bibliografica": review by G. Vivanti of Hadamard, *Four Lectures on Mathematics delivered at Columbia University in 1911* (New York, 1915), xi–xiii; review by G. L(oria) of C. J. Keyser, *The Humor Worth of Rigorous Thinking. Essays and Addresses* (New York, 1916), xix–xxi.

Esercitazioni Matematiche, volume 1, November–December, 1921: "La dimensionalità dello spazio" by B. Levi, 203–208; "Riduzione di una sostituzione lineare a forma canonica" by M. Cipolla, 209–220—Volume 2, January–February, 1922: Review by G. Mignosi of J. W. Young, *Fundamental Concepts of Algebra and Geometry*, Italian translation by D. Mercogliano, with preface by G. Loria, 50–53—March–April: "Le sostituzioni lineare che non alterano una quadrica" by G. Mignosi, 80–88; "La commemorazione di Ulisse Dini," 104–108; Letter from D. Mercogliano in regard to the review by G. Mignosi of Young's *Fundamental Concepts of Algebra and Geometry*, 121–123.

Nature, volume 109, May 6, 1922: "Text-books of elementary mathematics" by H. B. H., 574–576 [Brief notice of several text-books including Osgood, *Elementary Calculus* (Macmillan, New York, 1921)]; "Pythagoras's theorem as a repeating pattern" by J. R. Cotter, 579—May 20: "The general theory of relativity" by A. S. E., 634–636 [Review of H. Weyl, *Space—Time—Matter* (London, 1922)]; "On immediate solutions of some dynamical problems" by A. Gray, 645–647—June 3: "G.B.M." by A. Gray, 712 [Reminiscences of G. B. Mathews]; "The elliptic logarithmic spiral—a new curve" by H. S. Rowell, 716.

La Nature, volume 50_1, April 29, 1922: "Le télescope géant de M. Mac Afee et les canaux de Mars" by A. T., 270—May 13: "Einstein au Collège de France, Conférence de M. Einstein" by M. Morand, 298–303 (to be continued)—May 20: "Einstein au Collège de France, Discussion sur les théories" by M. Morand, 315–320.

Periodico di Matematiche, series 4, volume 2, March, 1922: ["Sulla teoria della relatività" by G. Todesco, 125–135 ["Dalle conferenze di Einstein a Bologna. Prima conferenza: Il principio speciale di relatività"]; "L'invenzione dei logaritmi" by A. Agostini, 135–150; "Assiomi e ipotesi dei *Fondamenti di Geometria* del Veronese" by F. Palatini, 150–163; "Sopra una proprietà del cerchio dei nove punti" by R. Zappa, 164–173; ["Prof. Umberto Scarpis," 219–220 [Tribute of the Council of the Italian Society, Mathesis]—May: "Sulla teoria della relatività" by G. Todesco, 221–236 ["Seconda conferenza: La relatività generale"]; "Gli incommensurabili e il procedimento euclideo del massimo comun divisore" by P. Cattaneo, 236–245; "Sulle funzioni iperboliche" by V. Notari, 246–260.

Philosophical Magazine, sixth series, volume 42, November, 1921: "On the transformation of the equation of motion of the dynamics of continuous media in the restricted principle of relativity" by H. T. Flint, 794–799; "The relativity of field and matter" by A. S. Eddington, 800–806; "On the postulates and conclusions of the theory of relativity" by L. T. More, 841–852—Volume 43, January, 1922: "The derivation of symmetrical gravitational fields" by F. D. Murnaghan, 19–31 ["In the usual treatment of this problem a field is said to be symmetrical about a point if the form for $(ds)^2$ is invariant under linear orthogonal transformations of the 'Cartesian coördinates' (x_1, x_2, x_3); then a transformation is made to 'polar coördinates' r, θ, ϕ, where $r = \sqrt{x_1^2 + x_2^2 + x_3^2}$, etc., and an appeal is made, in choosing a form for $(ds)^2$, to the corresponding form in Euclidean space. Now the essential assumption in the relativity theory of a permanent gravitational field is that the physical space-time continuum of four dimensions is *non*-Euclidean; the term 'Cartesian coördinates' for a non-Euclidean space requires definition, and the equation for r given above assumes an underlying Pythagorean theory that is not tenable for non-Euclidean spaces in general. Since the only existing experimental verifications of the relativity *gravitational theory* are based on the expression for $(ds)^2$ in a permanent symmetrical gravitational field, it is desirable that the assumptions in the mathematical treatment should be clearly stated."]; "On the significance of Einstein's gravitational equations in terms of the curvature of the world" by A. S. Eddington, 174–177 [Revision of a proof in volume 42, p. 800];

"On a graphical solution of a class of differential equations occurring in wireless telegraphy" by A. A. Robb, 206–215 [Given an equation of the type $d^2p/d\omega^2 + f(p)\cdot dp/d\omega + p = 0$, the expression $d^2p/d\omega^2 + p$ may be interpreted as the radius of curvature of a curve from which by mechanical means a second curve is drawn whose polar equation is a solution of the given equation. (Compare F. V. Morley's derivation of the differential equation arising from the curve of pursuit problem, *1921*, 55)]—February: "Method of tracing caustic curves" by A. S. Percival, 258–277—March: "The relation between the projective and the metrical scales, and its bearing on the theory of parallels" by L. Silberstein, 420–429; "The deflexion of a ray of light in the solar gravitational field" by F. D. Murnaghan, 580–588; "The identical relations in Einstein's theory" by G. B. Jeffery, 600–603—April: "On products of Legendre functions" by J. W. Nicholson, 768–784—May: "Circular plates of variable thickness" by G. D. Birkhoff, 953–962.

POPULAR ASTRONOMY, volume 30, June–July, 1922: "Photograph of a small tornado," 325–326; "The present position of the island universe theory of the spiral nebulæ" (concluded) by D. B. McLaughlin, 327–339; "Aberration and relativity" by W. H. Pickering, 340–343; "A universal scale for the solution of astronomical problems" by J. E. G. Yalden, 352–356 [Describes a device for the graphical solution of astronomical problems].

PROCEEDINGS OF THE LONDON MATHEMATICAL SOCIETY, series 2, volume 20, part 6, February, 1922: "On double surfaces" by B. M. Sen, 417–434—Part 7, April, Prefatory Matter: "Lord Rayleigh" by H. L., xliii–xlvii; "Adolf Hurwitz" by W. H. Y., xlviii–liv.

PROCEEDINGS OF THE ROYAL SOCIETY, series A, volume 100, December 1, 1921: "The principles of internal ballistics" by J. Proudman, 289–305—Volume 101, April 1, 1922: "The design of repeating patterns.—Part I" by P. A. MacMahon and W. P. D. MacMahon, 80–94 [Abstract in *Nature*, November 24, 1921, p. 421 (see *1922*, 75)]; "Correlation between arrays in a table of correlation" by C. Spearman, 94–100.

PROCEEDINGS OF THE ROYAL SOCIETY OF EDINBURGH, volume 41, part 2, 1920–21: "Note on a continuant of Cayley's of the year 1874" by T. Muir, 111–116.

QUARTERLY JOURNAL OF PURE AND APPLIED MATHEMATICS, volume 49, December, 1921: "On recurrences for sums of divisors" by E. T. Bell, 186–192.

RENDICONTI DEL CIRCOLO MATEMATICO DI PALERMO, volume 45, 1921: "On the relation between the Hilbert space and the calcul fonctionnel of Fréchet" by E. W. Chittenden, 265–270; "Orbits asymptotic to the straight line equilibrium points in the problem of three finite bodies" by D. Buchanan, 332–356—Volume 46, fasc. 1, 1922: "The Cauchy problem on the equation of telegraphy" by T. Hayashi, 117–121.

REVUE GÉNÉRALE DES SCIENCES, volume 33, April 15, 1922: "A propos de la théorie d'Einstein" by J. Richard, 193–194; "Sur la possibilité de se représenter l'espace fini et sans bornes de la théorie de la relativité" by R. Thiry, 205–209—April 30: "Sur la notion de courbure de l'espace" by R. Thiry, 225; "Coup d'œil sur les principes fondamentaux de la nomographie en quels cas et comment ils permettent de réduire à une représentation plane des dimensions en nombre supérieur à trois" by M. d'Ocagne, 230–239; "La démonstration scientifique" by R. d'Adhémar, 239–244 (to be continued)—May 15: "La démonstration scientifique" by R. d'Adhémar, 268–276.

PROBLEMS AND SOLUTIONS.

EDITED BY B. F. FINKEL, OTTO DUNKEL, AND H. P. MANNING.

Send all communications about Problems and Solutions to B. F. FINKEL, Springfield, Mo.

PROBLEMS FOR SOLUTION.

[N.B. Problems containing results believed to be new, or extensions of old results are especially sought. The editorial work would be greatly facilitated if, on sending in problems, proposers would also enclose any solutions or information that will assist the editors in checking the statements. In general, problems in well-known text-books, or results found in readily accessible sources, will not be proposed as problems for solution in the MONTHLY. In so far as possible, however, the editors will be glad to assist members of the Association with their difficulties in the solution of such problems.]

2972. Proposed by J. H. M. WEDDERBURN, Princeton University.

In *Mathematical Education*, p. 361, B. Branford gives the following approximate construction

for the trisection of an angle $A\hat{B}C$. Take any point D on AB produced and make $BC = BD$; through C draw a parallel to BA and on it lay off a length $CP = CD$; then $A\hat{B}P$ is approximately $\frac{1}{3}A\hat{B}C$. Show that this construction is rendered very much more accurate by laying off on CP a distance $CQ = 2BD$ and taking in place of P, the point R which divides PQ in the ratio 5 : 4. Also show that the error does not exceed 10″ for angles less than 45°.

2973. Proposed by N. K. CHAFFEE, Rutland, Vt.

A straight brass bar 800 feet long expands 8 inches. The ends are fixed, so that it is distorted. If the new shape is that of an arc of a circle of which the original bar is the chord, how far above the center of the bar in its original position will the center be in the new position?

It is instructive to guess at this distance before attempting to solve the problem.

2974. Proposed by the late L. G. WELD.

A man standing on a straight railway track watches a train starting from a station half a mile distant and notices that it approaches at such speed that each puff of the exhaust is heard at the same instant that the next succeeding puff is seen. How long will it be before the train reaches him, the drive wheels of the locomotive being sixteen feet in circumference?

2975. Proposed by the late ARTEMAS MARTIN.

What must be the form of the mold-board of a plow, considered as a warped surface, so that it will run most easily through the ground?

2976. Proposed by NATHAN ALTSHILLER-COURT, University of Oklahoma.

The base of a variable triangle is fixed, the opposite vertex describing a straight line. Find the locus of the symmedian point, the locus of the center of the nine-point circle, and the envelope of the Euler line.

SOLUTIONS.

2825 [1920, 186]. Proposed by the late L. G. WELD.

A ball, having a coefficient of resilience α, strikes a rigid plane surface, inclined at an angle θ from the horizontal, after falling through a height h. What is the distance from the first to the second point of impact with the plane?

SOLUTION BY WILLIAM HOOVER, Columbus, Ohio, and H. P. MANNING, Providence, R. I.

In this problem, the forces are impulsive. Let $u = \sqrt{2gh}$ be the velocity of the center of the ball when it impinges upon the plane for the first time at O; let the straight line through O directly down the plane be the axis of x, and the normal to the plane at O the axis of y; let v_x, v_y be the x and y components of the space velocity immediately after the first impact; and let X, Y be the corresponding reactions between the ball and plane, the mutual friction being such that the ball does not slip. Let m be the mass, and a the radius of the ball, and let k be its radius of gyration about a diameter.

First suppose $\alpha = 0$. Then, resolving parallel to the x and y axes, we have

$$m(v_x - u\sin\theta) = -X, \qquad m(v_y + u\cos\theta) = Y;$$

and, taking moments about the center of the ball, and putting ω = the angular velocity, we have also

$$mk^2\omega = Xa.$$

For the condition of no slipping, we have $v_x = a\omega$, and for $\alpha = 0$, $v_y = 0$. These equations give

$$X = \frac{mk^2u\sin\theta}{k^2 + a^2}, \qquad Y = mu\cos\theta. \tag{1}$$

Let v_x', v_y' be the velocities corresponding to v_x, v_y in the second case, when resilience is taken into account; then for X, Y we write $(1 + \alpha)X$, $(1 + \alpha)Y$, and the equations for linear motion become

$$m(v_x' - u\sin\theta) = -(1 + \alpha)X, \qquad m(v_y' + u\cos\theta) = (1 + \alpha)Y.$$

These combined with (1) give

$$v_x' = u \sin\theta \frac{a^2 - \alpha k^2}{a^2 + k^2}, \qquad v_y' = + u\alpha \cos\theta. \tag{2}$$

The equations of motion are $\ddot{x} = g \sin\theta$, $\ddot{y} = -g\cos\theta$, or $\dot{x} = gt\sin\theta + c_1$, $\dot{y} = -gt\cos\theta + c_2$. When $t = 0$, $\dot{x} = v_x'$ and $\dot{y} = v_y'$. Hence determining c_1 and c_2 from (2), we get

$$\dot{x} = \sin\theta\left(gt + u\frac{a^2 - \alpha k^2}{a^2 + k^2}\right), \qquad \dot{y} = \cos\theta\,(u\alpha - gt).$$

Integrating again, with the conditions $x = 0$ and $y = a$ when $t = 0$,

$$x = \sin\theta\left(\tfrac{1}{2}gt^2 + tu\frac{a^2 - \alpha k^2}{a^2 + k^2}\right), \qquad y = a + \cos\theta\,(u\alpha t - \tfrac{1}{2}gt^2).$$

The ball hits the plane a second time when $y = a$, i.e. when $t = 2u\alpha/g$. The corresponding value of x becomes, after simplification,

$$\frac{2a^2\alpha(1+\alpha)u^2}{g(a^2+k^2)}\sin\theta.$$

Also solved by H. L. Olson, Arthur Pelletier, and J. B. Reynolds.

2860 [1920, 428]. Proposed by E. O. BROWN, Chicago, Ill.

A frustum of a right circular cone has a volume v. The lateral area added to the lesser base is a sum which is a minimum. Determine the dimensions of the frustum in terms of v.

Solution by H. S. Uhler, Yale University.

Let h, r, R, and s denote respectively the altitude, the radius of the smaller base, the radius of the larger base, and the slant height of the frustum. Also let σ symbolize the sum in question. Then

$$\sigma = \pi(Rs + rs + r^2), \tag{1}$$

$$v = \tfrac{1}{3}\pi h(R^2 + Rr + r^2), \tag{2}$$

$$s = +[h^2 + (R - r)^2]^{1/2}. \tag{3}$$

By virtue of equations (2) and (3), σ may be considered as a function of the two independent variables R and r, hence the necessary conditions for a minimum of σ are

$$\frac{\partial\sigma}{\partial R} = 0, \qquad \frac{\partial\sigma}{\partial r} = 0.$$

Differentiating equations (1), (2), and (3) with respect to R and combining the results we obtain

$$\frac{\partial\sigma}{\partial R} = \frac{\pi}{s}\left\{s^2 + (R + r)\left[R - r - \frac{9v^2(2R + r)}{\pi^2(R^2 + Rr + r^2)^3}\right]\right\} = 0,$$

whence

$$\frac{9v^2}{\pi^2(R^2 + Rr + r^2)^3} = \frac{2(R - r)}{R + 2r}. \tag{4}$$

In like manner we find

$$\frac{\partial\sigma}{\partial r} = \frac{\pi r}{s}\left[2s - 2(R - r) - \frac{9v^2(2R + r)}{\pi^2(R^2 + Rr + r^2)^3}\right] = 0. \tag{5}$$

The ratio $r/R \equiv \rho$ may be obtained in the following manner. First substitute the equal of the left member of equation (4) in the third or fractional term of equation (5) to get

$$s = \frac{3(R^2 - r^2)}{R + 2r}. \tag{6}$$

Then square the last equation, eliminate v^2 by again using relation (4), and suppress the com-

mon factor $R - r$ to obtain $3\rho^3 + 5\rho^2 - 2 = 0$, the roots of this equation being

$$-1, \quad -(\sqrt{7}+1)/3, \quad (\sqrt{7}-1)/3.$$

Substituting the positive root in the following modified form of equation (4)

$$R^6 = \frac{9(1+2\rho)v^2}{2(1-\rho^3)(1+\rho+\rho^2)^2\pi^2},$$

we get

$$R = \frac{(88+13\sqrt{7})^{1/6}v^{1/3}}{2^{1/6}\cdot 7^{1/4}\pi^{1/3}} \doteq 0.833293v^{1/3},$$

and $r = \frac{1}{3}(\sqrt{7}-1)R \doteq 0.457131v^{1/3}$.

The values of h and s may now be obtained from formulas (2) and (6) respectively. They are $h = [2(\sqrt{7}-2)v/\pi]^{1/3} \doteq 0.743559v^{1/3}$, $s = R$.

The last relation is the most significant geometrically. Let θ denote the acute angle between the axis and the slant height of the frustum. Then

$$\theta = \sin^{-1}[(R-r)/s] = \sin^{-1}[(4-\sqrt{7})/3] \doteq 26^\circ\ 50'\ 4.5''.$$

From the practical point of view, the problem amounts to asking for the smallest amount of sheet metal out of which a cup or deep cake pan of given capacity can be made.

2870 [1921, 36]. Proposed by WARREN WEAVER, University of Wisconsin.

A pendulum bob of mass m is attached to one end of a weightless and inextensible string of length l and swings as a conical pendulum with an angular velocity ω_1 about a vertical line through a fixed point to which the other end of the string is attached. If the angular velocity is increased to ω_2, the height through which the bob rises is independent of the length l. Consider, then, a very long and a very short pendulum. Suppose they are each swung first with an angular velocity ω_1 and then with a larger angular velocity, ω_2, the difference between these two values being great enough so that the longer pendulum rises through a height greater than the length of the shorter pendulum. According to the above result, the shorter one should rise through this same height, which is obviously impossible. Explain this apparent paradox.

SOLUTION BY I. MAIZLISH, University of Minnesota.

Let l be the length of the string, α_1 the angle which the equilibrium position of the pendulum makes with the vertical when the angular velocity is ω_1, and α_2 the corresponding angle when the angular velocity is ω_2. Assume $\omega_2 > \omega_1$, that the pendulum is free to take a vertical position when not revolving, and that ω_1 and ω_2 are finite. It is readily seen that for equilibrium the following equation must hold:

$$\tan\alpha_1 = (\omega_1^2 l \sin\alpha_1)/g, \tag{1}$$

and if $\alpha_1 > 0$ we must have

$$\omega_1 > \sqrt{(g/l)}. \tag{2}$$

The height of the bob from the horizontal plane passing through it when the pendulum is in its vertical position is $h_1 = l(1-\cos\alpha_1) = l - (g/\omega_1^2)$, and if the angular velocity is increased from ω_1 to ω_2, α being increased to α_2, the height through which the bob rises will be

$$h_2 - h_1 = (g/\omega_1^2) - (g/\omega_2^2), \tag{3}$$

as long as $\omega_1 \geqq \sqrt{(g/l)}$.

Let l' be the length of the short pendulum. If ω_1 and ω_2 are chosen so that $(g/\omega_1^2) - (g/\omega_2^2) > l'$ we shall have $\omega_1 < \sqrt{(g/l')}$ and we cannot apply (3) to this pendulum. If $\omega_2 > \sqrt{(g/l')}$ and the bob of the short pendulum rises at all, the height to which it rises will be $l' - g/\omega_2^2$, but if $\omega_2 \leqq \sqrt{(g/l')}$, it will not rise at all.

Also solved by H. L. OLSON, F. L. WILMER and the PROPOSER.

2872 [1921, 36]. Proposed by W. D. LAMBERT, U. S. Coast and Geodetic Survey.

The rectangular coördinates of a point P at the time t are given by the equations

$$x = k\cos\gamma\cos(nt-\alpha), \qquad y = k\sin\gamma\cos(nt-\beta),$$

where k, γ, n, α, and β are constants and γ is taken in the first quadrant. An auxiliary angle δ, in the first quadrant, is defined by the equation

$$\sin \delta = \sin 2\gamma |\sin (\alpha - \beta)|.$$

(1) Show that P describes an ellipse the lengths of whose semi-axes are $k \cos \frac{1}{2}\delta$ and $k \sin \frac{1}{2}\delta$ and the inclinations of whose axes to the x-axis are given by

$$\tan 2\theta = \tan 2\gamma \cos (\alpha - \beta).$$

(2) Show that the time T when P is at the end of an axis is given by

$$\tan (2nT - \alpha - \beta) = \cos 2\gamma \tan (\alpha - \beta).$$

(3) Obtain criteria for distinguishing between the major and minor axes and for the direction of rotation of P and show that the quantities γ, $\alpha - \beta$, δ, θ and $nT - \alpha - \beta$ are simply related as the parts of a right spherical triangle, thus providing a partial check on the computation.

Solution by J. B. Reynolds, Lehigh University.

1. Eliminating t from the given parametric equations, we have

$$\alpha + \cos^{-1} \frac{x \sec \gamma}{k} = \beta + \cos^{-1} \frac{y \csc \gamma}{k},$$

or

$$\cos (\alpha - \beta) = \frac{xy \sec \gamma \csc \gamma}{k^2} + \frac{1}{k^2} \sqrt{k^2 - x^2 \sec^2 \gamma} \sqrt{k^2 - y^2 \csc^2 \gamma};$$

whence

$$x^2 \tan^2 \gamma + y^2 - 2xy \cos (\alpha - \beta) \tan \gamma - k^2 \sin^2 (\alpha - \beta) \sin^2 \gamma = 0 \tag{1}$$

is the rectangular equation of the curve, and is that of an ellipse with center at the origin. To ascertain the length s of the axes then, we need find only the maximum and minimum values of $r = \sqrt{x^2 + y^2}$. Now,

$$r^2 = x^2 + y^2 = k^2[\cos^2 \gamma \cos^2 (nt - \alpha) + \sin^2 \gamma \cos^2 (nt - \beta)]. \tag{2}$$

Setting the $d(r^2)/dt = 0$, we get

$$\tan 2nt = \frac{\cos^2 \gamma \sin 2\alpha + \sin^2 \gamma \sin 2\beta}{\cos^2 \gamma \cos 2\alpha + \sin^2 \gamma \cos 2\beta} = \frac{S}{C}, \quad \text{say;} \tag{3}$$

and we find

$$\sqrt{S^2 + C^2} = \sqrt{1 - \sin^2 2\gamma \sin^2 (\alpha - \beta)} = \cos \delta \text{ by the data given;}$$

whence

$$\sin 2nt = \pm \frac{S}{\cos \delta} \qquad \text{and} \qquad \cos 2nt = \pm \frac{C}{\cos \delta}.$$

Putting these values in (2), we get for maximum and minimum values of r^2,

$$\frac{k^2}{2}\left[1 \pm \left(\frac{S^2 + C^2}{\cos \delta}\right)\right] = \frac{k^2}{2}(1 \pm \cos \delta),$$

so that the major and minor semi-axes are $k \cos \delta/2$ and $k \sin \delta/2$. The angle made by these axes with the x-axis comes immediately from (1) by writing the condition for elimination of the term in xy or[1]

$$\tan 2\theta = \frac{-2 \cos (\alpha - \beta) \tan \gamma}{\tan^2 \gamma - 1} = \tan 2\gamma \cos (\alpha - \beta).$$

2. When the ends of the axes are reached, r is a maximum or minimum. In getting $d(r^2)/dt = 0$, we have

$$\cos^2 \gamma \sin (2nt - 2\alpha) + \sin^2 \gamma \sin (2nt - 2\beta) = 0.$$

[1] Similarly the expression for the semi-axes could be obtained by use of the invariants of rotation, and then the equation for T could be derived by algebraic processes. On the other hand, the equation for θ ($\tan \theta$ being y/x) could be deduced from the equation $d(r^2)/dt = 0$ without any reference to the theory of rotation of axes.—Editors.

Or, putting $\frac{1}{2}(1 + \cos 2\gamma)$ and $\frac{1}{2}(1 - \cos 2\gamma)$ for $\cos^2 \gamma$ and $\sin^2 \gamma$,

$$\sin (2nt - \alpha - \beta) \cos (\alpha - \beta) - \cos 2\gamma \cos (2nt - \alpha - \beta) \sin (\alpha - \beta) = 0;$$

and then replacing t by the particular value T at this time,

$$\tan (2nT - \alpha - \beta) = \cos 2\gamma \tan (\alpha - \beta).$$

3. The major semi-axis is $k \cos \delta/2$, δ being by hypothesis an angle in the first quadrant. Differentiating

$$\frac{y}{x} = \tan \gamma \frac{\cos (nt - \beta)}{\cos (nt - \alpha)},$$

we have for the angular velocity of P

$$\frac{n \tan \gamma \sin (\beta - \alpha)}{\cos^2 (nt - \alpha)},$$

positive or negative with $\sin (\beta - \alpha)$.

We can place 2γ on the hypotenuse, 2θ and δ on the legs of a right spherical triangle, $90° - (2nT - \alpha - \beta)$ opposite 2θ and $\alpha - \beta$ opposite δ on the angles; for the three equations

$$\sin \delta = \sin 2\gamma \sin (\alpha - \beta), \qquad \cos (\alpha - \beta) = \tan 2\theta \cot 2\gamma,$$
$$\cos 2\gamma = \cot (\alpha - \beta) \tan (2nT - \alpha - \beta)$$

will then conform to Napier's rules.[1]

2878 [1921, 89]. Proposed by R. S. HOAR, Fort Banks, Mass.

Consider the integers $0, 1, 2, 3 \cdots n - 1, n$. Consider all possible permutations of combinations of these taken r at a time, allowing any integer to occur more than once. Select from these permutations all groups the sum of whose integers is n. Form the reciprocal of the product of the factorials of the r integers of each of these selected groups. Then the sum of all of these reciprocals will equal $r^n/n!$. Prove that this must be so.

Example. $n = 2, r = 3$.

$$\frac{1}{2!0!0!} + \frac{1}{0!0!2!} + \frac{1}{0!2!0!} + \frac{1}{1!0!1!} + \frac{1}{1!1!0!} + \frac{1}{0!1!1!} = \frac{3^2}{2!}, \qquad \text{if} \qquad 0! = 1.$$

SOLUTION BY H. L. OLSON, University of Michigan, and PHILIP FRANKLIN, Princeton University.

By the multinomial theorem, we have

$$(x_1 + x_2 + \cdots + x_r)^n = \Sigma \frac{n!}{i_1!\, i_2! \cdots i_r!} x_1^{i_1} x_2^{i_2} \cdots x_r^{i_r},$$

where $i_1 + i_2 + \cdots + i_r = n$ and $i_1, i_2, \cdots, i_r \geqq 0$. If we set each x_i equal to unity and divide the two members of the equation by $n!$, we have the theorem stated.

2880 [1921, 89]. Proposed by SIDNEY DORB, Detroit, Mich.

Solve the simultaneous equations $xy = 2$, and

$$\left(3 - \frac{6y}{x - y}\right)^2 + \left(3 - \frac{6y}{x + y}\right)^2 = 82.$$

SOLUTION BY A. A. BENNETT, University of Texas.

It is assumed for various reasons that the second equation was intended in the form

$$\left(3 + \frac{6y}{x - y}\right)^2 + \left(3 - \frac{6y}{x + y}\right)^2 = 82,$$

[1] This supposes $\sin (\alpha - \beta)$ positive, and it would not essentially restrict the problem to assume that α and β are angles in the first quadrant, $\alpha > \beta$.

which makes the problem of interest. With this supposition, the pair of equations may be written as

$$xy = a,$$
$$\left(\frac{x+y}{x-y}\right)^2 + \left(\frac{x-y}{x+y}\right)^2 = 2b,$$

where $a = 2$, $b = 41/9$. It is then to be noted that if (r, s) be one solution, the following are the eight distinct solutions:

(r, s), (s, r), $(-r, -s)$, $(-s, -r)$, $(ir, -is)$, $(is, -ir)$, $(-ir, is)$, $(-is, ir)$.

Thus there is a group of eight operations carrying any solution into a solution. This remark applies for all finite non-vanishing values of a, b. Solutions can coincide in pairs only for a, or b, zero or infinite, or for $b = -1$. Since $(1, 2)$ is by inspection a solution, the eight solutions may be written out at once.

By direct methods also the solution is readily obtained. Put $u = (x + y)/(x - y)$; whence

$$x^2 = a(u + 1)/(u - 1),$$
$$y^2 = a(u - 1)/(u + 1),$$

where the signs of x and y are to be so taken that $xy = a$. Then

$$u^2 + 1/u^2 = 2b, \qquad u = \frac{\pm\sqrt{b+1} \pm \sqrt{b-1}}{\sqrt{2}}$$

In the given example $u = 3, -3, \frac{1}{3}$, or $-\frac{1}{3}$, $x^2 = 4, 1, -4, -1$, $y^2 = 1, 4, -1, -4$, and the solutions are

$$(2, 1), \quad (-2, -1), \quad (1, 2), \quad (-1, -2), \quad (2i, -i), \quad (-2i, i), \quad (i, -2i), \quad (-i, 2i).$$

NOTE.—Miss Berta M. King remarks that if the sign in the second equation is changed as stated in Professor Bennett's solution, the problem is in Hawkes's *Advanced Algebra*. She gets the same results as Professor Bennett.

H. N. CARLETON, A. R. NAUER, J. W. SHUMAN and F. L. WILMER solved the problem as it is printed above.

2898 [1921, 228]. Proposed by J. W. CLAWSON, Ursinus College.

Four straight lines determine four triangles. It is well known that the circumcenters of these triangles lie on a circle and that the circumcircles intersect this circle in a point, called the Wallace point. It is also well known that the orthocenters of the four triangles lie in a straight line, which is perpendicular to the line on which lie the middle points of the three diagonals of the quadrilateral determined by the four given straight lines.

Prove that the centroids of the four triangles lie on a parabola whose axis is parallel to the mid-diagonal line; and that the distance from the Wallace point to the mid-diagonal line is two thirds of the distance from the Wallace point to the axis of the parabola.

SOLUTION BY THE PROPOSER.

In the statement of the problem "two thirds" should be "three halves."

Given the four lines, let the origin be at the Wallace point. The Wallace or pedal lines of this point with respect to the four triangles are coincident. Let the y-axis be parallel to this line, its equation being, say, $x = p$. Then the perpendicular from the origin on the four given lines will meet them in four points on this line, which we may call (p, a), (p, b), (p, c), (p, d), and the equations of the four given lines will be

$$px + ay = p^2 + a^2, \text{ etc.}$$

The intersections of these lines are the six points

$$p - \frac{ab}{p},\ a + b, \text{ etc.},$$

and the mid-points of the three diagonals are

$$p - \frac{ab + cd}{2p},\ \tfrac{1}{2}(a + b + c + d), \text{ etc.},$$

so that the equation of the mid-diagonal line is $y = \frac{1}{2}(a + b + c + d)$. Also the centroids of the four triangles are

$$p - \frac{ab + ac + bc}{3p}, \ \tfrac{3}{4}(a + b + c), \text{ etc.}$$

The equation of a parabola whose axis is praallel to the x-axis is of the form[1]

$$y^2 + Dx + Ey + F = 0,$$

and if we substitute the coördinates of any three of the centroids, evaluate D, E, F, and simplify, we obtain the equation

$$\left(y - \frac{a + b + c + d}{3}\right)^2 = -\frac{4p}{3}\left(x - p - \frac{a^2 + b^2 + c^2 + d^2}{12p} + \frac{ab + ac + ad + bc + bd + cd}{6p}\right),$$

symmetrical with respect to a, b, c, d.

The axis of this parabola is $y = \frac{1}{4}(a + b + c + d)$; therefore, the distance of the mid-diagonal line from O is three halves of the distance of this axis from O.

We may note that the four orthocenters are

$$2p, \ a + b + c + \frac{abc}{p^2}, \text{ etc.},$$

all lying on the line $x = 2p$, which is twice as far from o as the pedal line.

2791 [1919, 414; 1921, 143–145].

A cup of wine is suspended over a cup of equal capacity full of water; through a small hole in the bottom, the wine drips into the water, and the mixture drips out at the same rate. When the wine cup is empty, what part of the contents of the lower cup is water? [Proposed by Charles Gilpin, Jr., Philadelphia, as Problem 287 in *The Mathematical Visitor*, January, 1881, volume 1, page 193. No solution was published in the *Visitor*.]

Remarks by R. E. Moritz, University of Washington.

Each of the solutions of the problem published in this Monthly (*1921*) proceeds on the assumption that the liquids flow from the cups, in other words, that the process by which the wine cup is emptied is a continuous process. This assumption seems to me unwarranted, being a flat contradiction of one of the conditions of the problem. The problem states explicitly that "the wine drips into the water, and the mixture drips out at the same rate." Dripping is essentially a discontinuous process, the solutions referred to must therefore be considered approximations rather than exact solutions.

Curiously enough, the exact solution is very much simpler than the approximations in question. Suppose that each cup contains at the outset n drops of equal size. After the first drop has fallen into the lower cup, the mixture consists of n drops of water and one drop of wine,[2] $n/(n + 1)$ of the contents of the lower cup is therefore water; after the second drop of wine has been added, the water content is $[n/(n + 1)]^2$; after the third drop has been added, $[n/(n + 1)]^3$; after the nth drop has been added, that is when the cup has been emptied, $[n/(n + 1)]^n$. It is clear then that the exact answer to the problem is a function of n, the number of drops in the wine cup at the outset.

The limit of $[n/(n + 1)]^n$ as n approaches ∞ is e^{-1}, which is the result obtained in the previous solutions. But n cannot be infinite, for if it were, the wine cup could not be emptied by a dripping process.

[1] That the coördinates of the four centroids satisfy an equation of this type may be seen from the fact that if we substitute them all and eliminate D, E and F, we get a polynomial of degree 5 in a, b, c, d, divisible by the six differences, $a - b$, etc., and, therefore, zero—Editors.

[2] This assumes that the cup can hold $n + 1$ drops till they are mixed—Editors.

NOTES AND NEWS.

It is hoped that readers of the MONTHLY will coöperate in contributing to the general interest of this department by sending items to H. P. MANNING, Brown University, Providence, R. I.

VICTOR DANTSCHER VON KOLLESBERG, born at Innsbruck, Austria, October 29, 1847, died July 26, 1921. He studied at Innsbruck, Berlin, and Vienna where he received his doctorate in 1870. His connection with the University of Graz dates from 1879; he became ordinary professor of mathematics there in 1894. The number of his mathematical papers is not numerous; apart from three in the *Mathematische Annalen*, most of them appeared in Austrian publications. His eighty-page pamphlet, *Vorlesungen über die Weierstrasssche Theorie der irrationalen Zahlen*, appeared at Leipzig, in 1908.

JACOB ROSANES, born at Brody, Austria, August 16, 1842, died January 7, 1922. Receiving his doctorate at Breslau in 1865, he became extraordinary professor of mathematics there in 1873, and ordinary professor in 1870. Since 1911 he had been excused from delivery of lectures. Most of his mathematical papers were published in *Journal für reine und angewandte Mathematik* and *Mathematische Annalen*, and they contain some notable results in algebraic geometry; compare *Jahresbericht der deutschen Mathematiker-Vereinigung*, volume 24, 1915, page 78.

GUSTAV KOHN, born in Reichenan, Bohemia, April 22, 1859, died December 15, 1921. He studied at Brelin, Strasbourg, and Vienna where he received his doctor's degree in 1881. In 1884 he became Privatdozent at the University of Vienna, and in 1894 extraordinary professor of mathematics. Most of his mathematical papers were published in *Sitzungsberichte der mathematisch-naturwissenschaftlichen Klasse der kaiserl. Akademie der Wissenschaften*, Vienna, and *Monatshefte für Mathematik und Physik*. He is perhaps best known, however, for the part of the *Encyklopädie der mathematischen Wissenschaften*, III–2–4, 5 (pages 457–634, 1908–1914), on "Spezielle ebene algebraische Kurven," prepared in collaboration with Gino Loria.

HUGO FERDINAND BUCHHOLZ, born in Lübeck, Germany in 1866, died November 24, 1921. He was educated in Jena, Stockholm, Berlin, and Munich, where he received his doctorate in 1894. He was assistant at the observatory in the University of Göttingen 1897–1900 and was later appointed "Titular-professor," while dozent in astronomy and applied mathematics, at the University of Halle. His first book (Leipzig, 1908) was *Das mechanische Potential. Nach Vorlesungen von L. Boltzmann bearbeitet und die Theorie der Figur der Erde. Zur Einführung in die höhere Geodäsie* (*angewandte Mathematik*), Theil 1; no other part appeared. A new edition (1916), nearly doubled in size (38 + 820 pages), had the title: *Angewandte Mathematik. Das mechanische Potential und seine Anwendung zur Bestimmung der Figur der Erde* (*höhere Geodäsie*). It will be recalled also that he was the editor of the third and enlarged edition (Leipzig, 1912) of the monumental *Theoretische Astronomie* by W. Klinkerfues.

KARL HERMANN AMANDUS SCHWARZ died in Berlin November 29th, 1921. He was born at Hermsdorf on January 25th, 1843. He took his doctorate at

Berlin in 1864; taught at Halle 1867–1869; at Zürich 1869–1875; and became professor at Göttingen in 1875. In 1892 he succeeded Weierstrass at Berlin. In 1902 he was awarded an honorary degree of Doctor of Mathematics by the University of Christiania. His most notable work was in geometry in connection with the theory of minimal surfaces; but his name will be familiar to students of mathematics through the Schwarz inequality and the Schwarz-Christoffel mapping of a linear polygon on the axis of reals in the theory of functions of a complex variable. The fiftieth anniversary of his doctorate was celebrated at Berlin on August 6, 1914, and was commemorated by a notable volume edited by Carathéodory, Hessenberg, Landau and Lichtenstein. His collected papers were published in two volumes in 1890 (Berlin).

MAX NÖTHER died at Erlangen on December 13, 1921. He was born at Mannheim on September 24, 1844. He attended the Universities of Heidelberg, Giessen and Göttingen; took his doctorate at Heidelberg in 1868; taught at Heidelberg 1874–1875 and went to Erlangen in 1875 where he was made professor in 1888. He made notable contributions to the geometry of curves and surfaces and the connected theory of algebraic functions; his name has been given to the fundamental theorem that every plane algebraic curve can be transformed birationally into one whose only singularities are double points with distinct tangents. In 1882 he shared with Halphen the Steiner prize of the Berlin Academy. He read a paper at the Chicago Mathematical Congress (1893). A detailed biography can be found in *Mathematische Annalen* (of which he was an editor), volume 85.

LEO KÖNIGSBERGER died at Heidelberg on December 15, 1921. He was born at Posen on October 15, 1837. He took his doctorate at Berlin in 1860; taught at Greifswald 1864–1866; was professor there 1866–1869; then at Heidelberg 1869–1875, Dresden Polytechnic 1875–1877, Vienna 1877–1884. Since 1884 he had been professor at Heidelberg. He published texts on ordinary differential equations (in which theory his best work was done) and the principles of mechanics. A paper by him appeared in *American Journal of Mathematics*, volume 11 (1889). A detailed biography and a photograph may be found in the index to volumes 1–35 of *Acta Mathematica*.

PAUL RUDOLPH EUGEN JAHNKE died at Berlin October 18, 1921. He was born at Berlin on November 30, 1863. He studied at Berlin 1881–1885 and took his doctorate at Halle 1889. He became Kneser's successor, in 1905, as professor of higher mathematics at the Bergakademie, Berlin. When this was taken over by the Technische Hochschule, Charlottenburg in 1916, he became a professor in the latter institution. His work was mainly in elliptic function theory; a short note by him appeared in the *American Journal of Mathematics*, volume 21 (1899). His name is familiar to workers in mathematical physics through the excellent book, Jahnke und Emde, *Funktionentafeln mit Formeln und Kurven* (Leipzig, 1909).

GEORGE BALLARD MATHEWS died March 19, 1922. He was born at London on February 23, 1861. He studied for a year under Henrici at Uni-

versity College, London, and entering St. John's College, Cambridge, took first place in the Tripos of 1883. In 1884 he was made professor in the newly created University of North Wales at Bangor. In 1897 he was elected a Fellow of the Royal Society and appointed University Lecturer in Mathematics at Cambridge. He returned to Bangor in 1906 where he taught till 1919, the remaining years of his life being clouded by ill health. He received the honorary degree of LL.D. from the University of Glasgow in 1915. His principal contributions to mathematics were in the theory of numbers and projective geometry. He published a *Theory of Numbers* (Cambridge, 1892); a *Treatise on Bessel Functions* (in collaboration with Professor Andrew Gray, London, 1895); *Algebraic Equations* (Cambridge Tracts, 1907); *Projective Geometry* (London, 1914), and also re-edited Scott's *Determinants* (Cambridge, 1904). He contributed frequent reviews and articles to *Nature* (London) and more detailed biographies may be found in that journal, volume 109, page 450, and in *Proceedings of the Royal Society of London*, September, 1922. In the latter the biographer comments on his powers of controversy in Latin elegiacs, his notable translations of Arabic poetry, and his extensive knowledge of music.

JAMES HENRY COTTERILL died on January 8, 1922. He was born at Norfolk, England, on November 2, 1836. In 1866 he was appointed lecturer and in 1870 vice-principal of the Royal School of Naval Architecture and Marine Engineering at South Kensington. In 1873 this school was moved to Greenwich and became part of the Royal Naval College, in which Professor Cotterill was professor of Applied Mathematics until his retirement in 1897. He was elected honorary vice-president of the Institution of Naval Architects in 1905. In 1878 he published a treatise on *The Steam Engine* (London) and in 1884 his *Applied Mechanics* (London). These have passed through several editions and have been widely used in the engineering schools of this country.

Published November 7, 1922.

THE MATHEMATICAL ASSOCIATION OF AMERICA

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FOR THE ACADEMIC YEAR 1922-1923

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For a list of all officers and Council Members or Trustees for preceding years see page 47.

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Closed for printing November 1, 1922.

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University of Virginia, University, Va.
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HARRISBURG. Whited.
HAVERFORD. Reid, A. H. Wilson.
LANCASTER. Charles.
LANSDOWNE. Chambers, Glenn.
LARIMER. A. A. Jones.
LEWISBURG. Bartol, Everett, Gold, Lowry.
LINCOLN UNIVERSITY. W. L. Wright.
LOCK HAVEN. High.
MEADVILLE. Akers.
MYERSTOWN. Kiess.
NEW WILMINGTON. McCain.
PHILADELPHIA. Burley, Crawley, Eshleman, H. B. Evans, Gehman, Kline, Linton, Partridge, Rittenhouse, Safford.
PITTSBURGH. Baird, Barrett, Bishop, Bland, Foraker, R. F. Johnson, J. H. Mathews, Riggs, Rosenbach, Swartzel, Taber, Waltz, Webber.
POTTSTOWN. Arms.
SOUTH BETHLEHEM. Lambert, MacNutt.
STATE COLLEGE. Gravatt, L. S. Johnston, Shibli.
SWARTHMORE. Marriott, J. A. Miller.
UNIONTOWN. M. Buchanan.
WASHINGTON. Atchison, Bert, R. W. Thomas.
WEST PHILADELPHIA. Latshaw.

PHILIPPINE ISLANDS. (5)

MANILA. V. Mills, Ott, Rafferty, Schick, H. L. Smith.

PORTO RICO. (1)

MAYAGUEZ. C. E. Horne.

RHODE ISLAND. (11)

EDEN PARK. C. R. Adams.
PROVIDENCE. Archibald, R. W. Burgess, Burwell, Carlen, Chace, Currier, Gilman, Hicks, H. P. Manning, R. G. D. Richardson.

SOUTH CAROLINA. (7)

CHARLESTON. O. J. Bond.
COLUMBIA. Coleman, J. B. Jackson.
GREENVILLE. Earle, R. B. Wood.
HARTSVILLE. C. M. Reaves.
SALUDA. Ramage.

SOUTH DAKOTA. (4)

BROOKINGS. I. L. Miller.
RAPID CITY. McLaury.
VERMILION. McKinney.
YANKTON. Faught.

TENNESSEE. (8)

CHATTANOOGA. Hooper.
CLARKSVILLE. Higgins.
KNOXVILLE. J. D. Bond, Brezler.
MARYVILLE. Knapp.
NASHVILLE. S. I. Jones, Schuerman.
SEWANEE. S. M. Barton.

TEXAS. (52)

ABILENE. Burnam.
ARLINGTON. Baten.
AUSTIN. Batchelder, H. Y. Benedict, A. A. Bennett, Calhoun, Cleveland, Cooper, Decherd, Ettlinger, Hammer, Holmes, Horton, Jacobs, Michie, R. L. Moore, I. I. Nelson, M. B. Porter, Rockwell, R. L. Wilder.
BOERNE. Hathaway.
BROWNSVILLE. de la Garza.
CANYON. L. G. Allen.
COLLEGE STATION. Cox, P. K. Smith.
COMMERCE. Cowling.
DALLAS. Dice, E. H. Jones, Mahoney.
FORT WORTH. Hargett, E. R. Tucker.
GALVESTON. Burrell, P. H. Underwood.
GEORGETOWN. Wunder.
HOUSTON. Daniell, Dean, G. C. Evans, L. R. Ford, Lovett, Michal.
PALESTINE. Eason.
PORT ARTHUR. G. S. Smith.
SAN ANGELO. Hagelstein.
SAN ANTONIO. B. R. Allen, Roach.
SAN MARCOS. J. S. Brown, Sewell.
SHERMAN. P. F. Henry.
STEPHENVILLE. J. L. Riley.
WACO. W. A. Nelson, P. C. Porter.
WICHITA FALLS. H. Porter.

UTAH. (5)

LOGAN. Saxer.
SALT LAKE CITY. J. L. Gibson, Horsfall, Pehrson, Unseld.

VERMONT. (5)

BURLINGTON. Swift, E. Thomas.
ESSEX JUNCTION. Donahue.
MIDDLEBURY. Bonney, Perkins.

VIRGINIA. (27)

ABINGDON. V. L. Wright.
ASHLAND. T. McN. Simpson.
BLACKSBURG. Brodie, Gudheim, O'Shaughnessy, J. E. Williams.
BRIDGEWATER. Shull.
BRISTOL. Holtwick
CHARLOTTESVILLE. F. A. Wells.
CLIFTON STATION. O. Stone.
EMORY. J. S. Miller.
HOLLINS. Dickinson, Plapp.
LEXINGTON. L. W. Smith, C. W. Watts.
LYNCHBURG. Larew, Shackelford, E. V. Watts.
MONTEREY. Colaw.
RICHMOND COLLEGE. Gaines.
SALEM. Carpenter.
SOUTH HILL. Walton.
SWEET BRIAR. Morenus.
UNIVERSITY. W. H. Echols, Luck.
WILLIAMSBURG. Rowe.
WOODBERRY FOREST. W. L. Lord.

WASHINGTON. (13)

ABERDEEN. V. Young.
EVERETT. Robb.
PULLMAN. Freeman, Isaacs.
SEATTLE. E. T. Bell, Moritz, Neikirk, Stager.
SPOKANE. Hess.
ST. JOHN. Hays.
TACOMA. Hanawalt.
WALLA WALLA. Bratton, Eells.

WEST VIRGINIA. (7)

HUNTINGTON. Hackney.
MORGANTOWN. H. A. Davis, Eiesland, Harkins, Hodgson, C. N. Reynolds, Torrey.

WISCONSIN. (33)

BELOIT. H. H. Conwell, W. A. Hamilton, Haynes.
MADISON. F. E. Allen, Chapman, H. T. Davis, Dowling, Dresden, Fowlkes, W. W. Hart, Lane, E. B. Miller, Rechard, Skinner, Slichter, Van Vleck, W. Weaver.
MERCER. Kendrigan.
MILTON. A. E. Whitford.
MILWAUKEE. Atwater, F. A. Bixby, Ericson, P. H. Evans, Frumveller, L. E. McCarty, C. G. Simpson, Thayer.
PLATTEVILLE. Warner.

RIPON. Woodmansee.
RIVER FALLS. McMillan.
SINSINAWA. Sr. Dobbin.
SOUTH MILWAUKEE. Hoar.
SUPERIOR. C. W. Smith.

WYOMING. (6)

CASPER. Counts.
LARAMIE. Bellamy, Feddersen, Fehn, Fitterer, Stromquist.

FOREIGN MEMBERS. (Other than Canada.)

ARGENTINE. (2)

BUENOS AIRES. Baidaff, Broggi.

BELGIUM. (1)

LIEGE. Van Hee.

CHINA. (8)

CHANGSHA. Leavens.
FOOCHOW. Yen.
PEKING. Chang Shen-Fu, Heinz, Hsia, Konantz.
SHANGHAI. Ely.
TANGSHAN. Patten.

ENGLAND. (8)

CAMBRIDGE. Ball, Richmond, P. W. Wood.
HOVE. Chepmell.
LONDON. Forsyth, Greenhill.
OXFORD. Hardy.
PETERSFIELD. Zilliacus.

FRANCE. (5)

BESANÇON. Lebeuf.
NANCY. Gérardin.
PARIS. Borel, Hadamard.
STRASBOURG. Fréchet.

INDIA. (4)

ALLAHABAD CITY. Mitra.
CALCUTTA. Bose.
DHARWAR. Saldanha.
VEDARANIAM. Ramana-Sastrin.

ITALY. (6)

BOLOGNA. Bortolotti, Enriques, Pincherle.
CATANIA. Cipolla.
PISA. Bianchi.
TURIN. Fubini.

JAPAN. (5)

PYENGYANG. Parker.
KOREA. Andrew.
SAITAMA-KEN. Sekiyama.
TOKYO. Mikami, Ono.

NEW ZEALAND. (1)

DUNEDIN. Martyn.

POLAND. (1)

WARSAW. Dickstein.

PORTUGAL. (1)

LISBON. da Cunha.

SCOTLAND. (1)

EDINBURGH. Horsburgh.

SOUTH AFRICA. (3)

BLOEMFONTEIN. Arndt.
JOHANNESBURG. Dalton.
RONDEBOSCH. Muir.

SPAIN. (2)

MADRID. de Toledo.
ZARAGOZA. de Galdeano.

SWITZERLAND. (3)

FRIBOURG. Bays.
GENEVA. Fehr.
NEUCHATEL. DuPasquier.

SYRIA. (1)

BEIRUT. Jurdak.

TURKEY. (2)

CONSTANTINOPLE. K. S. Arnold, Mourad.

RECAPITULATION OF MEMBERSHIP.

Individual members November 1, 1922	1,382	
Institutional members November 1, 1922	94	
Total membership November 1, 1922		1,476
Total membership October 1, 1919		1,187

CHARTER MEMBERSHIP.

Individual charter members	1,045	
Institutional charter members	52	
Total charter membership		1,097
Net gain in individual members	337	
Net gain in institutional members	42	
Total net gain over charter membership		379
Total net gain since October 1, 1919		289

BY-LAWS OF THE MATHEMATICAL ASSOCIATION OF AMERICA (INCORPORATED).

(As amended and adopted by unanimous vote at a special meeting of members called for the purpose at Rochester, N. Y., September 7, 1922, a quorum being present.)

ARTICLE I—NAME, PURPOSE AND CORPORATE SEAL.

1. This organization shall be known as

THE MATHEMATICAL ASSOCIATION OF AMERICA (INCORPORATED).

2. Its object shall be to assist in promoting the interests of mathematics in America, especially in the collegiate field, by holding meetings in any part of the United States or Canada for the presentation and discussion of mathematical papers, by the publication of mathematical papers, journals, books, monographs and reports, by conducting investigations for the purpose of improving the teaching of mathematics, by accumulating a mathematical library and by coöperating with other organizations whenever this may be desirable for attaining these or similar objects.

3. The Corporate Seal of the Association shall have inscribed thereon the name of the Association and the words "Corporate Seal—Illinois."

ARTICLE II—MEMBERSHIP.

1. Any person who is interested in the field of collegiate mathematics shall be eligible for election to membership in the Association.

2. Any institution in which the Calculus is regularly taught shall be eligible for election to institutional membership in the Association. Such an institution shall have the privilege of sending a voting delegate to the meetings of the Association.

3. Election to membership shall be by vote of the Board upon written application from the individual or institution seeking admission, endorsed in the case of individuals by two members of the Association.

4. Those who were admitted to membership in The Mathematical Association of America (unincorporated) prior to October 1, 1920, and were in good standing as such on that date, were thereby admitted to membership in this Association (Incorporated).

ARTICLE III—BOARD OF TRUSTEES AND OFFICERS.

1. The Officers of the Association shall be a President, two (2) Vice-Presidents, a Secretary-Treasurer, a Librarian and three (3) members of a Committee on Official Journal.

2. The control and management of the affairs and funds of the Association shall be vested in a Board of twenty (20) Trustees (hereinafter called the "Board"), who shall be members of the Association. This Board shall consist of the officers of the Association and twelve (12) additional members.

3. The President and Vice-Presidents shall be elected by the Association's members annually for a term of one year, and four members of the Board shall be elected by the Association's members annually for a term of three years. They shall be eligible for reëlection, but not for more than two (2) consecutive terms. The Secretary-Treasurer, the Librarian, and the Committee on Official Journal, consisting of the Editor-in-Chief, the Manager and one other member, shall be appointed by the Board. All Officers and other Trustees shall hold over until their respective successors are elected or appointed and qualify.

4. The Board shall transact the official business of the Association and shall report its actions at the annual business meeting of the Association and in the official journal. A statement regarding any proposed action of the Board which makes or alters a question of policy shall be published in the official journal, or notice of such proposed action shall be mailed to each member, before final action has been taken, so that members of the Association may make known to the Board their individual views.

5. The Board shall have authority to fill vacancies *ad interim* in any office, including vacancies in the Board and in the Committee on Official Journal, and to make any other appointments necessary for the transaction of the business of the Association.

6. At all meetings of the Board of Trustees a quorum shall consist of not less than five (5) members and no business may be validly transacted at a meeting at which less than a quorum is present; *provided* that any meeting of the Board, whether or not a quorum be present, may be

adjourned to a specified time and place by a majority of the members present without notice to the members at large other than announcement at such meeting. Informal action based on a mail ballot by the members of the Board, if ratified at a properly convened meeting of the Board, shall be as valid and effective as if originally authorized at such meeting.

7. Approximately two months before the date of the annual meeting all members shall be given an opportunity to nominate by mail a candidate for each office to be filled by the members for the ensuing year. Approximately one month before the annual meeting the Board shall announce two candidates for each office to be filled by the members, one being the person who received the highest vote in the nominations and the other being selected from among the several nominees next in order. The election shall be by mail or in person and shall close on the day of the annual meeting.

8. The President shall be the Executive Officer of the Association, shall preside at all meetings of the Board of Trustees and at the annual meeting of the Association. He shall have the usual duties pertaining to his office and such other duties as may from time to time be assigned him by the Board of Trustees.

9. The Vice-Presidents shall, in the absence of the President, have and exercise the powers of the President, their order being determined alphabetically. The Board of Trustees may assign to the Vice-Presidents such duties as may from time to time be determined.

10. The Secretary-Treasurer shall have the usual duties pertaining to the office of Secretary and of Treasurer, including the custody of the records of the Association and of its Corporate Seal, the keeping of minutes of the meetings of the Board of Trustees and of the annual meeting and special meetings of members, and giving of due notice of all regular and special meetings of the Association and of the Board of Trustees and the supervision and safe-keeping of the funds of the Association. The Secretary-Treasurer shall also have the duty of seeing that whenever Trustees are elected, including the election of Trustees to fill vacancies, a Certificate, under the Seal of the Association, giving the names of those elected and the term of their office, shall be recorded in the Office of the Recorder of Deeds for Cook County, Illinois. Such Certificate shall be signed by the Secretary-Treasurer and verified by oath of the President.

11. The Committee on Official Journal shall have supervision of the official journal subject to the control of the Board of Trustees.

12. The Librarian shall have general charge of the library of the Association and shall direct its affairs, including the exchange of the publications of the Association, subject to the control of the Board.

Article IV—Meetings.

1. A meeting of the Association shall be held annually, at such time and place as the Board may direct. Special meetings of the Association may be called from time to time by the Board, or while the Board is not in session by the President of the Association, to be held at such time and place as may appear from the call.

2. The outgoing Board shall hold a meeting immediately preceding the annual meeting of the Association next succeeding their election, and the members of the new Board shall hold a meeting and organize, by completing the Board, immediately succeeding the annual meeting of the Association at which the new members thereof were elected. Further meetings of the Board may be held from time to time at the call of the President or of any three (3) members of the Board.

3. Notice of any meeting of members of the Association shall be given by the Secretary-Treasurer at least thirty (30) days prior to the date set for such meeting. Notice of all meetings of the Board other than the regular meetings provided in Section 2 shall be given to each member of the Board at least fifteen (15) days prior to the date set therefor.

4. Any member of the Association or of the Board may waive notice with the same effect as if due notice had been given him.

5. At all meetings of the Association a quorum shall consist of not less than twenty-five (25) members and no business may be validly transacted at a meeting at which less than a quorum is present; *provided* that any meeting of the Association, whether or not a quorum be present, may be adjourned to a specified time and place by a majority of the members present without notice to the members at large other than the announcement at such meeting.

6. Members may take part and vote in person or by proxy at all meetings of the Association.

Article V—Sections.

1. Any group of not less than ten (10) members of this Association may petition the Board for authority to organize a Section of the Association for the purpose of holding local meetings.

The Board shall have power to specify the conditions under which such authority shall be granted.

2. The Association shall not be obligated to pay from its treasury any of the expenses of such Sections.

ARTICLE VI—OFFICIAL PUBLICATIONS.

1. The Association shall publish an official journal, which shall be sent free to all members of the Association in accordance with Article VII.

2. The Board shall have full control of the publication and sale of the official journal and of all other official publications.

3. The official journal shall be under the general management of the Committee on Official Journal. There shall also be appointed by the Board a body of Associate Editors who shall give assistance in connection with the official journal and under the direction of the Committee on Official Journal.

4. The Board shall from time to time, as the need arises, make special provision for the management of any other official publications.

5. The Board shall fix the price of the official journal and of any other official publications of the Association, but in no case shall the journal be sold to non-members for less than the annual dues of individual members.

ARTICLE VII—DUES.

1. Individual members of the Association shall pay an initiation fee of Two Dollars ($2) at the time of election.

2. The annual dues of each individual member shall be Four Dollars ($4), including a subscription to the official journal.

3. The annual dues of each institutional member shall be Seven Dollars ($7), including two (2) subscriptions to the official journal.

4. All dues shall be payable on the first of January of each year. Should the annual dues of any member remain unpaid beyond a reasonable time, his name shall be dropped from the list, after due notice.

5. New members entering the Association after April 1 of any year shall have their dues pro rated for the balance of the year, except when they desire to receive the full current volume of the official journal.

6. The life membership fee shall be the present value, according to McClintock's Male Annuitant Table based upon four (4) per cent. interest, of an immediate annuity of Four Dollars ($4) a year at the attained age of the member; an annual valuation of the life membership fund shall be made under the McClintock Male Four (4) Per Cent. Table; and the reserve thus computed shall be held as a liability.

ARTICLE VIII—AMENDMENTS TO THE ARTICLES OF ASSOCIATION AND BY-LAWS.

1. Changes in the Articles of Association or amendments to the By-Laws may be made at any annual meeting of the Association, or at any adjourned session thereof, or at any special meeting of the Association called for such purpose, by a two-thirds (⅔) vote of those present and entitled to vote; *provided* that due notice concerning such amendment shall have been printed in the official journal, or mailed to each member, at least one (1) month before the date of such meeting.

2. No changes in the Articles of Association shall have legal effect until a certificate thereof, verified by oath of the President and under Seal of the Association, attested by the Secretary-Treasurer, shall be filed in the office of the Secretary of State of the State of Illinois and recorded in the office of the Recorder of Deeds for Cook County, Illinois.

AMENDMENT TO THE ARTICLES OF ASSOCIATION.

(This amendment was adopted by unanimous vote at a special meeting of members called for the purpose at Rochester, N. Y., September 7, 1922, a quorum being present.)

Section 3 of the Articles of Association of The Mathematical Association of America (Incorporated) as amended on September 10, 1920, shall be further amended to read as follows: "The management of the aforesaid Association shall be vested in a Board of twenty (20) Trustees."

PERIODS OF SERVICE OF THE OFFICERS OF THE ASSOCIATION.

PRESIDENTS.

E. R. HEDRICK....1916
FLORIAN CAJORI....1917
E. V. HUNTINGTON....1918
H. E. SLAUGHT....1919
D. E. SMITH....1920
G. A. MILLER....1921
R. C. ARCHIBALD....1922

VICE-PRESIDENTS.

E. V. HUNTINGTON....1916
G. A. MILLER....1916
D. N. LEHMER....1917, 1918
OSWALD VEBLEN....1917
J. W. YOUNG....1918
R. G. D. RICHARDSON....1919
H. L. RIETZ....1919
HELEN A. MERRILL....1920
E. J. WILCZYNSKI....1920
R. C. ARCHIBALD....1921
R. D. CARMICHAEL....1921, 1922
B. F. FINKEL....1922

SECRETARY-TREASURER.

(Appointed by the Council or Board after 1918.)

W. D. CAIRNS....1916–

COMMITTEE ON PUBLICATIONS.

(Appointed by the Council or Board.)

H. E. SLAUGHT....1916–
R. D. CARMICHAEL....1916–1918
W. H. BUSSEY....1916–1918
R. C. ARCHIBALD....1919–1921
W. A. HURWITZ....1919–1921
A. A. BENNETT....1922–
H. P. MANNING....1922–

ELECTED MEMBERS OF THE COUNCIL OR BOARD.

D. N. LEHMER....1916–1918, 1922–
R. E. MORITZ....1916–1918
K. D. SWARTZEL....1916
OSWALD VEBLEN....1916, 1920–
R. C. ARCHIBALD....1916–1917
FLORIAN CAJORI....1916, 1918–
M. B. PORTER....1916–1917
J. W. YOUNG....1916–1917, 1920–
B. F. FINKEL....1916–1921
E. H. MOORE....1916–1921
J. N. VAN DER VRIES....1916–1918
ALEXANDER ZIWET....1916–1918
E. R. HEDRICK....1917–1922
HELEN A. MERRILL....1917–1919
D. E. SMITH....1917–1919, 1921–
ELIZABETH B. COWLEY....1918–1920
G. A. MILLER....1918–1920, 1922–
E. J. WILCZYNSKI....1918–1919, 1922–
L. P. EISENHART....1919–
E. V. HUNTINGTON....1917, 1919–
E. L. DODD....1920
R. D. CARMICHAEL....1920
A. A. BENNETT....1921
H. L. RIETZ....1921–
C. F. GUMMER....1921–

Important Notice

The Mathematical Association of America, like all other organizations of an educational character, gives manifold more than it receives from its constituents. This discrepancy is accounted for by the gratuitous and arduous work given to the Association by its devoted servants.

Since it is impossible to raise the dues above a certain maximum without going beyond the reach of very many of those to whom the Association means most, it seems clear that an endowment fund is the best solution of the difficulty. Now that the Association is incorporated it is legally qualified to administer such a fund.

An endowment is needed not only to prevent a reduction of the number of pages in the MONTHLY, but also to enable the Association to make just compensation to its servants, and to go forward with its important projects such, for example, as the preparation and publication of a Mathematical Dictionary which is so greatly needed in the English language.

It is believed that, when these conditions are widely known among the friends of mathematics, financial support of this kind will be forthcoming.

Legal Form for Gifts and Bequests

I hereby give[1] to the Board of Trustees of the Mathematical Association of America the sum of ..... Dollars, to be known as the ..... Fund, and to be used[2] for { Endowment—the income only of which may be expended. / Special Projects—for which both principal and income may be expended.

Witness: Signature .....

.....

[1] In case of a bequest, the first line should read "I hereby give and bequeath," etc.

[2] Indicate which one of the two purposes is desired, and omit the other.

THE APRIL MEETING OF THE ILLINOIS SECTION.

The third annual meeting of the Illinois Section of the Mathematical Association of America was held at Rockford College, Rockford, Illinois, on April 28 and 29, 1922, in conjunction with the Illinois State Academy of Science. There were three sessions; on Friday afternoon Chairman Comstock presided, on Friday night at a joint meeting of the Academy and the Illinois Section President Knipp of the Academy presided, and at the Saturday morning session Professor Miller presided.

There were forty-two in attendance, including the following nineteen members of the Association:

C. E. Comstock, M. W. Coultrap, A. Emch, R. M. Ginnings, W. A. Hamilton, E. S. Haynes, J. M. Kinney, E. B. Lytle, W. D. MacMillan, L. E. Mensenkamp, Bessie I. Miller, E. J. Moulton, Mary W. Newson, C. I. Palmer, S. F. Parson, I. Roman, L. S. Shively, H. E. Slaught, and G. E. Wahlin.

The following officers were elected: G. T. SELLEW, chairman; C. E. COMSTOCK, vice-chairman; G. H. SCOTT, secretary-treasurer. It was suggested by unanimous vote that the next meeting of the Illinois Section be held again with the annual meeting of the Illinois State Academy of Science but the power to fix the time and place of the next meeting was given to the executive committee.

A committee consisting of E. J. MOULTON, chairman, C. E. COMSTOCK and E. B. LYTLE was appointed to report at the next meeting on the best courses in mathematics for college freshmen consistent with present standards of high school preparation.

The Illinois Section and the State Academy were entertained at a cafeteria dinner Thursday evening at the Rockford High School and at a banquet on Friday evening at Rockford College.

The following papers were presented:

(1) "Constructive methods in geometry" by Professor ARNOLD EMCH;

(2) "Some aspects of correlation theory" by Mr. L. E. MENSENKAMP;

(3) "Romance in science. An experimental course offered by a mathematics department" by Professor BESSIE I. MILLER;

(4) "Consistency in grading mathematics papers" by Professor E. J. MOULTON;

(5)[1] An illustrated address on "Cosmogony" by Professor W. D. MACMILLAN;

Discussion of the National Committee's Report on College Entrance Requirements.

(6) Professor G. E. WAHLIN;

(7) Professor S. F. PARSON;

(8) Dr. J. M. KINNEY;

Discussion of how many and what mathematics courses should be offered to college freshmen.

(9) Professor E. B. LYTLE;

[1] This paper was presented at the joint session on Friday evening.